| **Pre-Kindergarten** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** | |
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| **Grade Band Theme:** Observations of the Environment  *This theme focuses on helping students develop the skills for systematic discovery to understand the science of the physical world around them in greater depth by using scientific inquiry.* | | | | | | |
| ***Strand Connections:*** *Observations of both living and nonliving things in local surroundings. This includes water, the sun, rocks and soil, human-made materials and living organisms. This encourages the examination and exploration of the environment.* | | | | | | |
| **Earth and Space Science (ESS)** | | | | | | |
| **Content Statement**  **Weather changes every day.**  Wind, water and temperature are all part of daily weather changes. Weather changes throughout the day and from day to day.  **Note:** Seasonal change can be included, based on observable changes as appropriate for this age. This topic is found at greater depth in Kindergarten and grade 5. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **The sun and the moon are visible at different times of the day or night.**  The sun is visible only in the daytime, but the moon is visible sometimes at night and sometimes during the day. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partial**  **\_\_\_ Does not** |  | |
| **Water can be observed as lakes, ponds, rivers, streams, the ocean, rainfall, hail, sleet or snow.**  When it rains, water can create puddles or cause flooding. The puddles and flooding eventually go away. Some areas flood more than others. The ocean is the largest body of water on Earth. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partial**  **\_\_\_ Does not** |  | |
| **Rocks and soil have properties that can help identify them.**  Rocks and soil have different colors and textures. Rocks and soil can be sorted by different colors and textures. |  | **\_\_ Full**  **\_\_ Partial**  **\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partial**  **\_\_\_ Does not** |  | |
| **Life Science (LS)** | | | | | | |
| **Content Statement**  **There are many distinct environments in Ohio that support different kinds of organisms.**  Plants and animals have traits that improve their chances of living in different environments.  Plants and animals in Ohio interact with one another for food, shelter and nesting. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **Similarities and differences exist among individuals of the same kinds of plants and animals.**  Individuals among plants and animals of the same kind show greater likeness than difference, even though they vary in some traits and behaviors.  Living things have physical traits and behaviors, which influence their survival.  Physical traits and behaviors of plants and animals are sometimes the same and sometimes different from the characteristics ascribed to them in stories. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **Physical Science (PS)** | | | | | | |
| **Content Statement**  **Objects and materials are described by their properties.**  Color, shape, size, weight and texture are some examples of characteristics that can be used to describe and/or sort objects and materials. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **Many objects can be made to produce sound.**  Sound can be produced by touching,  blowing or tapping objects. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **Kindergarten** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
| **Grade Band Theme: Observations of the Environment**  *This theme focuses on helping students develop the skills for systematic discovery to understand the science of the physical world around them in greater depth by using scientific inquiry.* | | | | | |
| ***Strand Connections:*** *Living and nonliving things have specific physical properties that can be used to sort and classify. The physical properties of air and water are presented as they apply to weather.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **Weather changes are long-term and short-term.**  Weather changes occur throughout the day and from day to day.  Air is a nonliving substance that surrounds Earth and wind is air that is moving.  Wind, temperature and precipitation can be used to document short-term weather changes that are observable.  Yearly weather changes (seasons) are observable patterns in the daily weather changes. **Note:** The focus is on observing the weather patterns of seasons. The reason for changing seasons is not appropriate for this grade level; this is found in grade 5. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **The moon, sun and stars can be observed at different times of the day or night.**  The moon, sun and stars are in different positions at different times of the day or night. Sometimes the moon is visible during the night, sometimes the moon is visible during the day and at other times, the moon is not visible at all. The observable shape of the moon changes in size very slowly throughout each day of every month. The sun is visible only during the day.  The sun’s position in the sky changes in a single day and from season to season. Stars are visible at night, some are visible in the evening or morning and some are brighter than others. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partial**  **\_\_\_ Does not** |  |
| **Life Science (LS)** | | | | | |
| **Content Statement**  **Living things are different from nonliving things.**  Living things include anything that is alive or has ever been alive. Living things have specific characteristics and traits. Living things grow and reproduce. Living things are found almost everywhere in the world. There are somewhat different kinds in different places.  **Note 1:** The focus is on the traits and  behaviors of living things not on  attributes of nonliving things. See  Kindergarten Physical Science for  nonliving things.  **Note 2:** Listing the characteristics that distinguish living things from nonliving things is not appropriate at this grade level. Further details will appear in the model curriculum. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Living things have physical traits and behaviors, which influence their survival.**  Living things are made up of a variety of structures. Some of these structures and behaviors influence their survival.  **Note:** This concept is addressed in PreK, but is included here for districts that do not have a PreK program. Further information for districts is provided in the model curriculum section. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Physical Science (PS)** | | | | | |
| **Content Statement**  **Objects and materials can be sorted and described by their properties.**  Objects can be sorted and described by the properties of the materials from which they are made. Some of the properties can include color, size and texture. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Some objects and materials can be made to vibrate to produce sound.**  Sound is produced by touching, blowing or tapping objects. The sounds that are produced vary depending on the properties of objects. Sound is produced when objects vibrate. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **Grade One** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Grade Band Theme: Observations of the Environment**  *This theme focuses on helping students develop the skills for systematic discovery to understand the science of the physical world around them in greater depth by using scientific inquiry.* | | | | | |
| ***Strand Connections:*** *Energy is observed through movement, heating, cooling and the needs of living organisms.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **The sun is the principal source of energy.**  Sunlight warms Earth’s land, air and water. The amount of exposure to sunlight affects the amount of warming or cooling of air, water and land. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **The physical properties of water can change.**  These changes occur due to changing energy. Water can change from a liquid to a solid and from a solid to a liquid. Weather observations can be used to examine the property changes of water.  **Note:** Water as a vapor is not  introduced until grade 2; only solid and  liquid water should be discussed at this  level. A broader coverage of states of  matter is found in grade 4. This concept  builds on the PS Kindergarten strand  pertaining to properties (liquids and  solids). |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partial**  **\_\_\_ Does not** |  |
| **Life Science (LS)** | | | | | |
| **Content Statement**  **Living things have basic needs, which are met by obtaining materials from the physical environment.**  Living things require energy, water and a particular range of temperatures in their environments.  Plants get energy from sunlight. Animals get energy from plants and other animals.  Living things acquire resources from the living and nonliving components of the environment. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Living things survive only in environments that meet their needs.**  Resources are necessary to meet the needs of an individual and populations of individuals. Living things interact with their physical environments as they meet those needs.  Effects of seasonal changes within the local environment directly impact the availability of resources. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Physical Science (PS)** | | | | | |
| **Content Statement**  **Properties of objects and materials can change.**  Objects and materials change when exposed to various conditions, such as heating or freezing. Not all materials change in the same way.  **Note 1:** Changes in temperature are a  result of changes in energy.  **Note 2:** Water changing from liquid to solid and from solid to liquid is found in ESS grade 1. |  | **\_\_\_ Full**  **\_\_\_ Partial** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Objects can be moved in a variety of ways, such as straight, zigzag, circular and back and forth.**  The position of an object can be described by locating it relative to another object or to the object’s surroundings.  An object is in motion when its position is changing.  The motion of an object can be affected by pushing or pulling. A push or pull is a force that can make an object move faster, slower or go in a different direction.  **Note:** Changes in motion are a result of changes in energy. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **Grade Two** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Grade Band Theme: Observations of the Environment**  *This theme focuses on helping students develop the skills for systematic discovery to understand the science of the physical world around them in greater depth by using scientific inquiry.* | | | | | |
| ***Strand Connections:*** *Living and nonliving things may move. A moving object has energy. Air moving is wind and wind can make a windmill turn. Changes in energy and movement can cause change to organisms and the environments in which they live.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **The atmosphere is made up of air.**  Air has properties that can be observed and measured. The transfer of energy in the atmosphere causes air movement, which is felt as wind. Wind speed and direction can be measured.  **Note:** Air is introduced in ESS Kindergarten and can be linked to PS and LS. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Water is present in the air.**  Water is present in the air as clouds, steam, fog, rain, ice, snow, sleet or hail. When water in the air cools (change of energy), it forms small droplets of water that can be seen as clouds. Water can change from liquid to vapor in the air and from vapor to liquid. The water droplets can form into raindrops. Water droplets can change to solid by freezing into snow, sleet or hail. Clouds are moved by flowing air.  **Note:** This concept builds upon the changing properties of water from ESS grade 1. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Long- and short-term weather changes occur due to changes in energy.**  Changes in energy affect all aspects of weather, including temperature, precipitation amount and wind.  **Note:** Discussion of energy at this grade level should be limited to observable changes. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Life Science (LS)** | | | | | |
| **Content Statement**  **Living things cause changes on Earth.**  Living things function and interact with their physical environments. Living things cause changes in the environments where they live; the changes can be very noticeable or slightly noticeable, fast or slow.  **Note:** At this grade level, discussion is limited to changes that can be easily observed. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Some kinds of individuals that once lived on Earth have completely disappeared, although they were something like others that are alive today.**  Living things that once lived on Earth no longer exist; their basic needs were no longer met. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Physical Science (PS)** | | | | | |
| **Content Statement**  **Forces change the motion of an object.**  Motion can increase, change direction or stop depending on the force applied.  The change in motion of an object is related to the size of the force.  Some forces act without touching, such as using a magnet to move an object or objects falling to the ground.  **Note:** At this grade level, gravitational and magnetic forces should be introduced through observation and experimentation only. The definitions of these forces should not be the focus of the content statements. |  | **\_\_\_ Full**  **\_\_\_ Partial** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **Grade Three** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Grade Band Theme: Interconnections within Systems**  *This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.* | | | | | |
| ***Strand Connections:*** *Matter is what makes up all substances on Earth. Matter has specific properties and exists in different states. Earth’s resources are made of matter. Matter can be used by living things and can be used for the energy they contain. There are many different forms of energy. Each living component of an ecosystem is composed of matter and uses energy.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **Earth’s nonliving resources have specific properties.**  Soil is composed of pieces of rock, organic material, water and air and has characteristics that can be measured and observed. Rocks have unique characteristics that allow them to be sorted and classified. Rocks form in different ways. Air and water are nonliving resources. **Note 1:** Rock classification is not the focus for this grade level; this is found in grade 6. At this grade, the actual characteristics of rocks can be used to sort or compare, rather than formal classification. **Note 2:** Properties of air and water have been addressed in PreK. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Earth’s resources can be used for energy.**  Many of Earth’s resources can be used for the energy they contain. Renewable energy is an energy resource, such as wind, water or solar energy, that is replenished within a short amount of time by natural processes. Nonrenewable energy is an energy resource, such as coal or oil, that is a finite energy source that cannot be replenished in a short amount of time. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Some of Earth’s resources are limited.**  Some of Earth’s resources become limited due to overuse and/or contamination. Reducing resource use, decreasing waste and/or pollution, recycling and reusing can help conserve these resources. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Life Science (LS)** | | | | | |
| **Offspring resemble their parents and each other.**  Individual organisms inherit many traits from their parents indicating a reliable way to transfer information from one generation to the next.  Some behavioral traits are learned through interactions with the environment and are not inherited. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Individuals of the same kind differ in their traits and sometimes the differences give individuals an advantage in surviving and reproducing.**  Plants and animals have physical features that are associated with the environments where they live.  Plants and animals have certain physical or behavioral characteristics that improve their chances of surviving in particular environments.  Individuals of the same kind have different characteristics that they have inherited. Sometimes these different characteristics give individuals an advantage in surviving and reproducing.  **Note:** The focus is on the individual, not the population. Adaption is not the focus at this grade level. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Plants and animals have life cycles that are part of their adaptations for survival in their natural environments.**  Over the whole earth, organisms are growing, reproducing, dying and decaying. The details of the life cycleare different for different organisms, which affects their ability to survive and reproduce in their natural environments.  **Note:** The names of the stages within  the life cycles are not the focus.  **Note:** New organisms are produced by the old ones**.** |  |  |  |  |  |
| **Physical Science (PS)** | | | | | |
| **All objects and substances in the natural world are composed of matter.**  Matter takes up space and has mass\*.  \*While mass is the scientifically correct term to use in this context, the [NAEP 2009 Science Framework](http://www.nagb.org/publications/frameworks/science-09.pdf) (page 27) recommends using the more familiar term "weight" in the elementary grades with the distinction between mass and weight being introduced at the middle school level.  In Ohio, students will not be assessed on the differences between mass and weight until Grade 6. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Matter exists in different states, each of which has different properties.**  The most common states of matter are solids, liquids and gases.  Shape and compressibility are properties that can distinguish between the states of matter.  One way to change matter from one state to another is by heating or cooling. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Heat, electrical energy, light, sound and magnetic energy are forms of energy.**  There are many different forms of energy. Energy is the ability to cause motion or create change.  **Note:** The different forms of energy that are outlined at this grade level should be limited to familiar forms of energy that a student is able to observe. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **Grade Four** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Grade Band Theme: Interconnections within Systems**  *This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.* | | | | | |
| ***Strand Connections:*** *Heat and electrical energy are forms of energy that can be transferred from one location to another. Matter has properties that allow the transfer of heat and electrical energy. Heating and cooling affect the weathering of Earth’s surface and Earth’s past environments. The processes that shape Earth’s surface and the fossil evidence found can help decode Earth’s history.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **Earth’s surface has specific characteristics and landforms that can be identified.**  About 70 percent of the Earth’s surface is covered with water and most of that is the ocean. Only a small portion of the Earth’s water is freshwater, which is found in rivers, lakes and ground water.  Earth’s surface can change due to erosion and deposition of soil, rock or sediment. Catastrophic events such as flooding, volcanoes and earthquakes can create landforms. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **The surface of Earth changes due to weathering.**  Rocks change shape, size and/or form due to water or ice movement, freeze and thaw, wind, plant growth, gases in the air, pollution and catastrophic events such as earthquakes, mass wasting, flooding and volcanic activity.  **Note:** The ice movement (above) refers to large bodies of ice, such as glaciers that can break large rocks into small ones. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **The surface of Earth changes due to erosion and deposition.**  Water, wind and ice physically remove and carry (erosion) rock, soil and sediment and deposit the material in a new location.  Gravitational force affects movements of water, rock and soil. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Life Science (LS)** | | | | | |
| **Changes in an organism’s environment are sometimes beneficial to its survival and sometimes harmful.**  Ecosystems can change gradually or dramatically. When the environment changes, some plants and animals survive and reproduce and others die or move to new locations. An animal’s patterns of behavior are related to the environment. This includes the kinds and numbers of other organisms present, the availability of food and resources, and the physical attributes of the environment. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Fossils can be compared to one another and to present-day organisms according to their similarities and differences.**  The concept of biodiversity is expanded to include different classification schemes based upon shared internal and external characteristics of organisms.  Most types of organisms that have lived on Earth no longer exist.  Fossils provide a point of comparison between the types of organisms that lived long ago and those existing today. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Physical Science (PS)** | | | | | |
| **The total amount of matter is conserved when it undergoes a change.**  When an object is broken into smaller pieces, when a solid is dissolved in a liquid or when matter changes state (solid, liquid, gas), the total amount of matter remains constant.  **Note 1:** At this grade, the discussion of  conservation of matter should be limited  to a macroscopic, observable level.  **Note 2:** States of matter are found in PS grade 3. Heating and cooling is one way to change the state of matter. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Energy can be transformed from one form to another or can be transferred from one location to another.**  Energy transfers from hot objects to cold objects as heat, resulting in a temperature change.  Electric circuits require a complete loop of conducting materials through which an electrical energy can be transferred.  Electrical energy in circuits can be transformed to other forms of energy, including light, heat, sound and motion. Electricity and magnetism are closely related |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **Grade Five** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Grade Band Theme: Interconnections within Systems**  *This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.* | | | | | |
| ***Strand Connections:*** *Cycles on Earth, such as those occurring in ecosystems, in the solar system, and in the movement of light and sound result in describable patterns. Speed is a measurement of movement. Change in speed is related to force and mass\*. The transfer of energy drives changes in systems, including ecosystems and physical systems.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **The solar system includes the sun and all celestial bodies that orbit the sun. Each planet in the solar system has unique characteristics.**  The distance from the sun, size, composition and movement of each planet are unique. Planets revolve around the sun in elliptical orbits. Some of the planets have moons and/or debris that orbit them. Comets, asteroids and meteoroids orbit the sun.  **Note:** The shape of Earth’s orbit is nearly circular (also true for other planets). Many graphics that illustrate the orbit overemphasize the elliptical shape, leading to the misconception regarding seasonal change being related to how close Earth is to the sun. The discussion of planet characteristics should be at an introductory level for this grade. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **The sun is one of many stars that exist in the universe.**  The sun appears to be the largest star in the sky because it is the closest star to Earth. Some stars are larger than the sun and some stars are smaller than the sun. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Most of the cycles and patterns of motion between the Earth and sun are predictable.**  Earth’s revolution around the sun takes approximately 365 days. Earth completes one rotation on its axis in a 24-hour period, producing day and night. This rotation makes the sun, stars and moon appear to change position in the sky. Earth’s axis is tilted at an angle of 23.5°. This tilt, along with Earth’s revolution around the sun, affects the amount of direct sunlight that the Earth receives in a single day and throughout the year. The average daily temperature is related to the amount of direct sunlight received. Changes in average temperature throughout the year are identified as seasons.  **Note 1:** The amount of direct sunlight  that Earth receives is related to the  altitude of the sun, which affects the  angle of the sun’s rays, and the amount  of time the sun is above the horizon  each day.  **Note 2:** Different regions around the world have seasonal changes that are not based solely on average temperature (e.g., rainy season, dry season, monsoon season). |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Life Science (LS)** | | | | | |
| **Organisms perform a variety of roles in an ecosystem.**  Populations of organisms can be categorized by how they acquire energy.  Food webs can be used to identify the relationships among producers, consumers and decomposers in an ecosystem. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **All of the processes that take place within organisms require energy.**  For ecosystems, the major source of energy is sunlight.  Energy entering ecosystems as sunlight is transferred and transformed by producers into energy that organisms use through the process of photosynthesis. That energy then passes from organism to organism as illustrated in food webs.  In most ecosystems, energy derived from the sun is transferred and transformed into energy that organisms use by the process of photosynthesis in plants and other photosynthetic organisms. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Physical Science (PS)** | | | | | |
| **The amount of change in movement of an object is based on the mass\* of the object and the amount of force exerted.**  Movement can be measured by speed. The speed of an object is calculated by determining the distance (d) traveled in a period of time (t).  Earth pulls down on all objects with a gravitational force. Weight is a measure of the gravitational force between an object and the Earth.  Any change in speed or direction of an object requires a force and is affected by the mass\* of the object and the amount of force applied.  **Note 1:** Gravity and magnetism are  introduced (through observation) in PS  grade 2.  \*While mass is the scientifically correct term to use in this context, the [NAEP 2009 Science Framework](http://www.nagb.org/publications/frameworks/science-09.pdf) (page 27) recommends using the more familiar term "weight" in the elementary grades with the distinction between mass and weight being introduced at the middle school level.  In Ohio, students will not be assessed on the differences between mass and weight until Grade 6. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Light and sound are forms of energy that behave in predictable ways.**  Light travels and maintains its direction until it interacts with an object or moves from one medium to another and then it can be reflected, refracted or absorbed.  Sound is produced by vibrating objects and requires a medium through which to travel. The rate of vibration is related to the pitch of the sound.  **Note:** At this grade level, the discussion of light and sound should be based on observable behavior. Waves are introduced at the middle school level. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **Grade Six** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Grade Band Theme: Order and Organization**  *This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be inferred by simple principles. These principles are related to the properties or interactions within and between systems.* | | | | | |
| ***Strand Connections:*** *All matter is made of small particles called atoms. The properties of matter are based on the order and organization of atoms and molecules. Cells, minerals, rocks and soil are all examples of matter.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **Minerals have specific, quantifiable properties.**  Minerals are naturally occurring, inorganic solids that have a defined chemical composition. Minerals have properties that can be observed and measured. Minerals form in specific environments. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Igneous, metamorphic and sedimentary rocks have unique characteristics that can be used for identification and/or classification.**  Most rocks are composed of one or more minerals, but there are a few types of sedimentary rocks that contain organic material, such as coal. The composition of the rock, types of mineral present, mineral arrangement, and/or mineral shape and size can be used to identify the rock and to interpret its history of formation, breakdown (weathering) and transport (erosion). |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Igneous, metamorphic and sedimentary rocks form in different ways.**  Magma or lava cools and crystallizes to form igneous rocks. Heat and pressure applied to existing rock forms metamorphic rocks. Sedimentary rock forms as existing rock weathers chemically and/or physically and the weathered material is compressed and then lithifies. Each rock type can provide information about the environment in which it was formed. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Soil is unconsolidated material that contains nutrient matter and weathered rock.**  Soil formation occurs at different rates and is based on environmental conditions, types of existing bedrock and rates of weathering. Soil forms in layers known as horizons. Soil horizons can be distinguished from one another based on properties that can be measured.  **Note:** The introduction to soil is found in grade 3. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Rocks, minerals and soils have common and practical uses.**  Nearly all manufactured material requires some kind of geologic resource. Most geologic resources are considered nonrenewable. Rocks, minerals and soil are examples of geologic resources that are nonrenewable.  **Note:** Nonrenewable energy sources should be included (such as fossil fuels). |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Life Science (LS)** | | | | | |
| **Cells are the fundamental unit of life.**  All living things are composed of cells. Different body tissues and organs are made of different kinds of cells. The ways cells function are similar in all living organisms.  **Note 1:** Specific information about the  organelles that need to be addressed at  this grade level will be found in the  model curriculum.  **Note 2:** Emphasis should be placed on the function and coordination of these components, as well as on their roles in overall cell function. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **All cells come from pre-existing cells.**  Cells repeatedly divide resulting in more cells and growth and repair in multicellular organisms.  **Note:** This is not a detailed discussion of the phases of mitosis or meiosis. The focus should be on reproduction as a means of transmitting genetic information from one generation to the next, cellular growth and repair. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Cells carry on specific functions that sustain life.**  Many basic functions of organisms occur in cells. Cells take in nutrients and energy to perform work, like making various molecules required by that cell or an organism.  Every cell is covered by a membrane that controls what can enter and leave the cell.  Within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback and movement.  **Note:** Emphasis should be placed on the function and coordination of cell components, as well as on their roles in overall cell function. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Living systems at all levels of organization demonstrate the complementary nature of structure and function.**  The level of organization within organisms includes cells, tissues, organs, organ systems and whole organisms.  Whether the organism is single-celled or multicellular, all of its parts function as a whole to perform the tasks necessary for the survival of the organism.  Organisms have diverse body plans, symmetry and internal structures that contribute to their being able to survive in their environments. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Physical Science (PS)** | | | | | |
| **All matter is made up of small particles called atoms.**  Each atom takes up space, has mass and is in constant motion. Mass is the amount of matter in an object.  Elements are a class of substances composed of a single kind of atom.  Molecules are the combination of two or more atoms that are joined together chemically.  Compounds are composed of two or more different elements. Each element and compound has properties, which are independent of the amount of the sample. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Changes of state are explained by a model of matter composed of atoms and/or molecules that are in motion.**  When substances undergo changes of state, neither atoms nor molecules themselves are changed in structure.  Thermal energy is a measure of the motion of the atoms and molecules in a substance.  Mass is conserved when substances undergo changes of state.  **Note:** Thermal energy can be connected to kinetic energy at this grade level. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Full**  **\_\_\_ Partially**  **\_\_\_ No** |  |
| **There are two categories of energy: kinetic and potential.**  Objects and substances in motion have kinetic energy.  Objects and substances can have energy as a result of their position (potential energy).  **Note:** Kinetic and potential energy should be introduced at the macroscopic level for this grade. Chemical and elastic potential energy should not be included at this grade; this is found in PS grade 8. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Full**  **\_\_\_ Partially**  **\_\_\_ No** |  |
| **An object’s motion can be described by its speed and the direction in which it is moving.**  An object’s position and speed can be measured and graphed as a function of time.  **Note 1:** This begins to quantify student  observations using appropriate  mathematical skills.  **Note 2:** Velocity and acceleration rates should not be included at this grade level; these terms are introduced in high school. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Full**  **\_\_\_ Partially**  **\_\_\_ No** |  |

| **Grade Seven** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Grade Band Theme: Order and Organization**  *This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be inferred by simple principles. These principles are related to the properties or interactions within and between systems.* | | | | | |
| ***Strand Connections:*** *Systems can exchange energy and/or matter when interactions occur within systems and between systems. Systems cycle matter and energy in observable and predictable patterns.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **The hydrologic cycle illustrates the changing states of water as it moves through the lithosphere, biosphere, hydrosphere and atmosphere.**  Thermal energy is transferred as water changes state throughout the cycle. The cycling of water in the atmosphere is an important part of weather patterns on Earth. The rate at which water flows through soil and rock is dependent upon the porosity and permeability of the soil or rock.  **Note:** Contamination can occur within any step of the hydrologic cycle. Ground water is easily contaminated as pollution present in the soil or spilled on the ground surface moves into the ground water and impacts numerous water sources. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Thermal-energy transfers in the ocean and the atmosphere contribute to the formation of currents, which influence global climate patterns.**  The sun is the major source of energy for wind, air and ocean currents and the hydrologic cycle. As thermal energy transfers occur in the atmosphere and ocean, currents form. Large bodies of water can influence weather and climate. The jet stream is an example of an atmospheric current and the Gulf Stream is an example of an oceanic current. Ocean currents are influenced by factors other than thermal energy, such as water density, mineral content (such as salinity), ocean floor topography and Earth’s rotation. All of these factors delineate global climate patterns on Earth.  **Note:** This content statement is related to LS grade 7 (biomes). Regional temperature and precipitation contribute to the identification of climatic zones. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **The atmosphere has different properties at different elevations and contains a mixture of gases that cycle through the lithosphere, biosphere, hydrosphere and atmosphere.**  The atmosphere is held to the Earth by the force of gravity. There are defined layers of the atmosphere that have specific properties, such as temperature, chemical composition and physical characteristics. Gases in the atmosphere include nitrogen, oxygen, water vapor, carbon dioxide and other trace gases. Biogeochemical cycles illustrate the movement of specific elements or molecules (such as carbon or nitrogen) through the lithosphere, biosphere, hydrosphere and atmosphere. **Note:**  The emphasis is on why the atmosphere has defined layers, not on naming the layers. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **The relative patterns of motion and positions of the Earth, moon and sun cause solar and lunar eclipses, tides and phases of the moon.**  The moon’s orbit and its change of position relative to the Earth and sun result in different parts of the moon being visible from Earth (phases of the moon).  A solar eclipse is when Earth moves into the shadow of the moon (during a new moon). A lunar eclipse is when the moon moves into the shadow of Earth (during a full moon).  Gravitational force between the Earth and the moon causes daily oceanic tides. When the gravitational forces from the sun and moon align (at new and full moons) spring tides occur. When the gravitational forces of the sun and moon are perpendicular (at first and last quarter moons), neap tides occur. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **Life Science (LS)** | | | | | | |
| **Matter is transferred continuously between one organism to another and between organisms and their physical environments.**  Plants use the energy in light to make sugars out of carbon dioxide and water (photosynthesis). These materials can be used and immediately stored for later use. Organisms that eat plants break down plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms.  Energy can transform from one form to another in living things. Animals get energy from oxidizing food, releasing some of its energy as heat.  The total amount of matter and energy remains constant, even though its form and location change. **Note 1:** Chemical reactions are resented as the  rearrangement of atoms in molecules.  **Note 2:** Chemical reactions in terms of subatomic structures of atoms are not appropriate. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **In any particular biome, the number, growth and survival of organisms and populations depend on biotic and abiotic factors.**  Biomes are regional ecosystems characterized by distinct types of organisms that have developed under specific soil and climatic conditions.  The variety of physical (abiotic) conditions that exists on Earth gives rise to diverse environments (biomes) and allows for the existence of a wide variety of organisms (biodiversity).  Ecosystems are dynamic in nature; the number and types of species fluctuate over time. Disruptions, deliberate or inadvertent, to the physical (abiotic) or biological (biotic) components of an ecosystem impact the composition of an ecosystem.  **Note:** Predator-prey and producer  consumer relations are addressed in  grade 5. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **Physical Science (PS)** | | | | | | |
| **The properties of matter are determined by the arrangement of atoms.**  Elements can be organized into families with similar properties, such as highly reactive metals, less-reactive metals, highly reactive nonmetals and some gases that are almost completely nonreactive.  Substances are classified according to their properties, such as metals and acids.  When substances interact to form new substances, the properties of the new substances may be very different from those of the old, but the amount of mass does not change.  **Note 1:** This is the conceptual  introduction of the Periodic table of  Elements.  **Note 2:** Acids and bases are included in  this topic; further detail will be provided  in the Model Curriculum.  **Note 3:** It is important to emphasize that most changes in the properties of matter have some combination of chemical and physical change (at different levels). |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **Energy can be transformed or transferred but is never lost.**  When energy is transferred from one system to another, the quantity of energy before transfer equals the quantity of energy after transfer. When energy is transformed from one form to another, the total amount of energy remains the same.  **Note:** Further discussion of energy transformation is addressed at the high school level. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |
| **Energy can be transferred through a variety of ways.**  Mechanical energy can be transferred when objects push or pull on each other over a distance.  Electromagnetic waves transfer energy when they interact with matter.  Thermal energy can be transferred through radiation, convection and conduction.  Electrical energy transfers when an electrical source is connected in a complete electrical circuit to an electrical device.  **Note 1:** Energy transfers should be  experiential and observable. This builds  upon PS grade 4 and is directly  connected to ESS grade 7 (thermal  energy transfers in the hydrologic  cycle).  **Note 2:** Electricity can be measured  through current, voltage and resistance.  In addition, renewable energy systems  should be included (such as wind,  geothermal, water or solar).  **Note 3:** The types of waves used within this topic include seismic, oceanic, sound and light. Seismic waves also are found in ESS grade 8. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  | |

| **Grade Eight** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Grade Band Theme: Order and Organization**  *This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be inferred by simple principles. These principles are related to the properties or interactions within and between systems.* | | | | | |
| ***Strand Connections:*** [***Strand Connections:***](#connections) *Systems can be described and understood by analysis of the interaction of their components. Energy, forces and motion combine to change the physical features of the Earth. The changes of the physical Earth and the species that have lived on Earth are found in the rock record. For species to continue, reproduction must be successful.* | | | | | |
| **Earth and Space Science (ESS)** | | | | | |
| **Content Statement**  **The composition and properties of Earth’s interior are identified by the behavior of seismic waves.**  The refraction and reflection of seismic waves as they move through one type of material to another is used to differentiate the layers of Earth’s interior. Earth has an inner and outer core, an upper and lower mantle, and a crust.  The formation of the planet generated heat from gravitational energy and the decay of radioactive elements, which are still present today. Heat released from Earth’s core drives convection currents throughout the mantle and the crust.  **Note:** The thicknesses of each layer of Earth can vary and be transitional, rather than uniform and distinct as often depicted in textbooks. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **A combination of constructive and destructive geologic processes formed Earth’s surface.**  Earth’s surface is formed from a variety of different geologic processes, including but not limited to plate tectonics.  **Note:** The introduction of Earth’s surface is found in ESS grade 4. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Evidence of the dynamic changes of Earth’s surface through time is found in the geologic record.**  Earth is approximately 4.6 billion years old. Earth history is based on observations of the geologic record and the understanding that processes observed at present day are similar to those that occurred in the past (uniformitarianism). There are different methods to determine relative and absolute age of some rock layers in the geologic record. Within a sequence of undisturbed sedimentary rocks, the oldest rocks are at the bottom (superposition). The geologic record can help identify past environmental and climate conditions.  **Note:** Environmental and climate conditions also can be documented through the cryosphere as seen through ice cores. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Life Science (LS)** | | | | | |
| **Reproduction is necessary for the continuation of every species.**  Every organism alive today comes from a long line of ancestors who reproduced successfully every generation. Reproduction is the transfer of genetic information from one generation to the next. It can occur with mixing of genes from two individuals (sexual reproduction). It can occur with the transfer of genes from one individual to the next generation (asexual reproduction). The ability to reproduce defines living things. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Diversity of species occurs through gradual processes over many generations. Fossil records provide evidence that changes have occurred in number and types of species.**  Fossils provide important evidence of how life and environmental conditions have changed.  Changes in environmental conditions can affect how beneficial a trait will be for the survival and reproductive success of an organism or an entire species.  Throughout Earth’s history, extinction of a species has occurred when the environment changes and the individual organisms of that species do not have the traits necessary to survive and reproduce in the changed environment. Most species (approximately 99 percent) that have lived on Earth are now extinct.  **Note:** Population genetics and the  ability to use statistical mathematics to  predict changes in a gene pool are  reserved for grade 10. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **The characteristics of an organism are a result of inherited traits received from parent(s).**  Expression of all traits is determined by genes and environmental factors to varying degrees. Many genes influence more than one trait, and many traits are influenced by more than one gene.  During reproduction, genetic information (DNA) is transmitted between parent and offspring. In asexual reproduction, the lone parent contributes DNA to the offspring. In sexual reproduction, both parents contribute DNA to the offspring.  **Note 1:** The focus should be the link  between DNA and traits without being  explicit about the mechanisms involved.  **Note 2:** The ways in which bacteria  reproduce is beyond the scope of this  content statement.  **Note 3:** The molecular structure of DNA is not appropriate at this grade level. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Physical Science (PS)** | | | | | |
| **Forces between objects act when the objects are in direct contact or when they are not touching.**  Magnetic, electrical and gravitational forces can act at a distance.  **Note:** Direct contact forces were addressed in the elementary grades. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Forces have magnitude and direction.**  The motion of an object is always measured with respect to a reference point.  Forces can be added. The net force on an object is the sum of all of the forces acting on the object. The net force acting on an object can change the object’s direction and/or speed.  When the net force is greater than zero, the object’s speed and/or direction will change.  When the net force is zero, the object remains at rest or continues to move at a constant speed in a straight line. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **There are different types of potential energy.**  Gravitational potential energy changes in a system as the masses or relative positions of objects are changed.  Objects can have elastic potential energy due to their compression or chemical potential energy due to the nature and arrangement of the atoms that make up the object. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **High School**  **Physical Science** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Course Description:**  Physical science is a high school level course that satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.  Physical science introduces students to key concepts and theories that provide a foundation for further study in other sciences and advanced science disciplines. Physical science comprises the systematic study of the physical world as it relates to fundamental concepts about matter, energy and motion. A unified understanding of phenomena in physical, living, Earth and space systems is the culmination of all previously learned concepts related to chemistry, physics, and Earth and space science, along with historical perspective and mathematical reasoning. | | | | | |
| **Study of matter:**  **Classification of Matter**   * Heterogeneous vs. homogeneous * Properties of matter * States of matter and its changes   Matter was introduced in the elementary grades and the learning progression continued through middle school to include differences in the physical properties of solids, liquids and gases, elements, compounds, mixtures, molecules, kinetic and potential energy and the particulate nature of matter. Content in the chemistry syllabus (e.g., electron configuration, molecular shapes, bond angles) will be developed from concepts in this course.  Matter can be classified in broad categories such as homogeneous and heterogeneous, or classified according to its composition or by its chemical (reactivity) and physical properties (e.g., color solubility, odor, hardness, density, melting point and boiling point, viscosity and malleability).  Solutions are homogenous mixtures of a solute dissolved in a solvent. The amount of a solid solute that can dissolve in a solvent generally increases as the temperature increases since the particles have more kinetic energy to overcome the attractive forces between them. Water is often used as a solvent since so many substances will dissolve in water. Physical properties can be used to separate the substances in mixtures, including solutions.  Phase changes can be represented by graphing the temperature of a sample vs. the time it has been heated. Investigations must include collecting data during heating, cooling and solid-liquid-solid phase changes. At times, the temperature will change steadily, indicating a change in the motion of the particles and the kinetic energy of the substance. However, during a phase change, the temperature of a substance does not change, indicating there is no change in kinetic energy. Since the substance continues to gain or lose energy during phase changes, these changes in energy are potential and indicate a change in the position of the particles. When heating a substance, a phase change will occur when the kinetic energy of the particles is great enough to overcome the attractive forces between the particles; the substance then melts or boils. Conversely, when cooling a substance, a phase change will occur when the kinetic energy of the particles is no longer great enough to overcome the attractive forces between the particles; the substance then condenses or freezes. Phase changes are examples of changes that can occur when energy is absorbed from the surroundings (endothermic) or released into the surroundings (exothermic).  When thermal energy is added to a solid, liquid or gas, most substances increase in volume because the increased kinetic energy of the particles causes an increased distance between the particles. This results in a change in density of the material. Generally, solids have greater density than liquids, which have greater density than gases due to the spacing between the particles. The density of a substance can be calculated from the slope of a mass vs. volume graph. Differences in densities can be determined by interpreting mass vs. volume graphs of the substances. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Atoms**   * Models of the atom (components) * Ions (cations and anions) * Isotopes   Content introduced in middle school, where the atom was introduced as a small, indestructible sphere, is further developed in the physical science syllabus. Over time, technology was introduced that allowed the atom to be studied in more detail. The atom is composed of protons, neutrons and electrons that have measurable properties, including mass and, in the case of protons and electrons, a characteristic charge. When bombarding thin gold foil with atomic-sized, positively charged, high-speed particles, a few of the particles were deflected slightly from their straight-line path. Even fewer bounced back toward the source. This evidence indicates that most of an atom is empty space with a very small positively charged nucleus. This experiment and other evidence indicate the nucleus is composed of protons and neutrons, and electrons that move about in the empty space that surrounds the nucleus. Additional experimental evidence that led to the development of other historic atomic models will be addressed in the chemistry syllabus.  All atoms of a particular element have the same atomic number; an element may have different isotopes with different mass numbers. Atoms may gain or lose electrons to become anions or cations. Atomic number, mass number, charge and identity of the element can be determined from the numbers of protons, neutrons and electrons. Each element has a unique atomic spectrum that can be observed and used to identify an element. Atomic mass and explanations about how atomic spectra are produced are addressed in the chemistry syllabus. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Periodic Trends of the Elements**   * Periodic law * Representative groups   Content from the middle school level, specifically the properties of metals and nonmetals and their positions on the periodic table, is further expanded in this course. When elements are listed in order of increasing atomic number, the same sequence of properties appears over and over again; this is the periodic law. The periodic table is arranged so that elements with similar chemical and physical properties are in the same group or family. Metalloids are elements that have some properties of metals and some properties of nonmetals. Metals, nonmetals, metalloids, periods and groups or families including the alkali metals, alkaline earth metals, halogens and noble gases can be identified by their position on the periodic table. Elements in Groups 1, 2 and 17 have characteristic ionic charges that will be used in this course to predict the formulas of compounds. Other trends in the periodic table (e.g., atomic radius, electronegativity, ionization energies) are found in the chemistry syllabus. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Bonding and Compounds**   * Bonding (ionic and covalent) * Nomenclature   Middle school content included compounds are composed of atoms of two or more elements joined together chemically. In this course, the chemical joining of atoms is studied in more detail. Atoms may be bonded together by losing, gaining or sharing electrons to form molecules or three-dimensional lattices. An ionic bond involves the attraction of two oppositely charged ions, typically a metal cation and a nonmetal anion formed by transferring electrons between the atoms. An ion attracts oppositely charged ions from every direction, resulting in the formation of a three-dimensional lattice. Covalent bonds result from the sharing of electrons between two atoms, usually nonmetals. Covalent bonding can result in the formation of structures ranging from small individual molecules to three-dimensional lattices (e.g., diamond). The bonds in most compounds fall on a continuum between the two extreme models of bonding: ionic and covalent.  Using the periodic table to determine ionic charge, formulas of ionic compounds containing elements from groups 1, 2, 17, hydrogen and oxygen can be predicted. Given a chemical formula, a compound can be named using conventional systems that include Greek prefixes where appropriate. Prefixes will be limited to represent values from one to 10**.** Given the name of an ionic or covalent substance, formulas can be written. Naming organic molecules is beyond this grade level and is reserved for an advanced chemistry course. Prediction of bond types from electronegativity values, polar covalent bonds, writing formulas and naming compounds that contain polyatomic ions or transition metals will be addressed in the chemistry syllabus. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Reactions of Matter**   * Chemical reactions * Nuclear reactions   In middle school, the law of conservation of matter was expanded to chemical reactions, noting that the number and type of atoms and the total mass are the same before and after the reaction. In this course, conservation of matter is expressed by writing balanced chemical equations. At this level, reactants and products can be identified from an equation and simple equations can be written and balanced given either the formulas of the reactants and products or a word description of the reaction. Stoichiometric relationships beyond the coefficients in a balanced equation and classification of types of chemical reactions are addressed in the chemistry syllabus.  During chemical reactions, thermal energy is either transferred from the system to the surroundings (exothermic) or transferred from the surroundings to the system (endothermic). Since the environment surrounding the system can be large, temperature changes in the surroundings may not be detectable.  While chemical changes involve changes in the electrons, nuclear reactions involve changes to the nucleus and involve much larger energies than chemical reactions. The strong nuclear force is the attractive force that binds protons and neutrons together in the nucleus. While the nuclear force is extremely weak at most distances, over the very short distances present in the nucleus the force is greater than the repulsive electrical forces among protons. When the attractive nuclear forces and repulsive electrical forces in the nucleus are not balanced, the nucleus is unstable. Through radioactive decay, the unstable nucleus emits radiation in the form of very fast-moving particles and energy to produce a new nucleus, thus changing the identity of the element. Nuclei that undergo this process are said to be radioactive. Radioactive isotopes have several medical applications. The radiation they release can be used to kill undesired cells (e.g., cancer cells). Radioisotopes can be introduced into the body to show the flow of materials in biological processes.  For any radioisotope, the half-life is unique and constant. Graphs can be constructed that show the amount of a radioisotope that remains as a function of time and can be interpreted to determine the value of the half-life. Half-life values are used in radioactive dating.  Other examples of nuclear processes include nuclear fission and nuclear fusion. Nuclear fission involves splitting a large nucleus into smaller nuclei, releasing large quantities of energy. Nuclear fusion is the joining of smaller nuclei into a larger nucleus accompanied by the release of large quantities of energy. Nuclear fusion is the process responsible for formation of all the elements in the universe beyond helium and the energy of the sun and the stars.  Further details about nuclear processes including common types of nuclear radiation, predicting the products of nuclear decay, mass-energy equivalence and nuclear power applications are addressed in the chemistry and physics syllabi. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Energy and Waves**   * Conservation of energy * Quantifying kinetic energy * Quantifying gravitational potential energy * Energy is relative * Transfer and transformation of energy (including work) * Waves * Refraction, reflection, diffraction, absorption, superposition * Radiant energy and the electromagnetic spectrum * Doppler shift * Thermal energy * Electricity * Movement of electrons * Current * Electric potential (voltage) * Resistors and transfer of energy   **Energy and Waves**  Building upon knowledge gained in elementary and middle school, major concepts about energy and waves are further developed. Conceptual knowledge will move from qualitative understandings of energy and waves to ones that are more quantitative using mathematical formulas, manipulations and graphical representations.  **Energy and Waves:**  **Conservation of energy**   * Quantifying kinetic energy * Quantifying gravitational potential energy * Energy is relative   Energy content learned in middle school, specifically conservation of energy and the basic differences between kinetic and potential energy, is elaborated on and quantified in this course. Energy has no direction and has units of Joules (J). Kinetic energy, *Ek*, can be mathematically represented by *Ek = ½mv2*. Gravitational potential energy, *Eg*, can be mathematically represented by *Eg = mgh*,. The amount of energy of an object is measured relative to a reference that is considered to be at a point of zero energy. The reference may be changed to help understand different situations. Only the change in the amount of energy can be measured absolutely. The conservation of energy and equations for kinetic and gravitational potential energy can be used to calculate values associated with energy (i.e., height, mass, speed) for situations involving energy transfer and transformation. Opportunities to quantify energy from data collected in experimental situations (e.g., a swinging pendulum, a car travelling down an incline) must be provided. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Transfer and transformation of energy (including work)**  In middle school, concepts of energy transfer and transformation were addressed, including conservation of energy, conduction, convection and radiation, the transformation of electrical energy, and the dissipation of energy into thermal energy. Work also was introduced as a method of energy transfer into or out of the system when an outside force moves an object over a distance. In this course, these concepts are further developed. As long as the force, **F**, and displacement, ***Δx,*** are in the same direction, work, *W*, can be calculated from the equation *W =* ***FΔx***. Energy transformations for a phenomenon can be represented through a series of pie graphs or bar graphs. Equations for work, kinetic energy and potential energy can be combined with the law of conservation of energy to solve problems. When energy is transferred from one system to another, some of the energy is transformed to thermal energy. Since thermal energy involves the random movement of many trillions of subatomic particles, it is less able to be organized to bring about further change. Therefore, even though the total amount of energy remains constant, less energy is available for doing useful work. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Waves**   * Refraction, reflection, diffraction, absorption, superposition * Radiant energy and the electromagnetic spectrum * Doppler shift   As addressed in middle school, waves transmit energy from one place to another, can transfer energy between objects and can be described by their speed, wavelength, frequency and amplitude. The relationship between speed, wavelength and frequency also was addressed in middle school Earth and Space Science as the motion of seismic waves through different materials is studied.  In elementary and middle school, reflection and refraction of light were introduced, as was absorption of radiant energy by transformation into thermal energy. In this course, these processes are addressed from the perspective of waves and expanded to include other types of energy that travel in waves. When a wave encounters a new material, the new material may absorb the energy of the wave by transforming it to another form of energy, usually thermal energy. Waves can be reflected off solid barriers or refracted when a wave travels form one medium into another medium. Waves may undergo diffraction around small obstacles or openings. When two waves traveling through the same medium meet, they pass through each other then continue traveling through the medium as before. When the waves meet, they undergo superposition, demonstrating constructive and destructive interference. Sound travels in waves and undergoes reflection, refraction, interference and diffraction. In the physics syllabus, many of these wave phenomena will be studied further and quantified.  Radiant energy travels in waves and does not require a medium. Sources of light energy (e.g., the sun, a light bulb) radiate energy continually in all directions. Radiant energy has a wide range of frequencies, wavelengths and energies arranged into the electromagnetic spectrum. The electromagnetic spectrum is divided into bands: radio (lowest energy), microwaves, infrared, visible light, X-rays and gamma rays (highest energy) that have different applications in everyday life. Radiant energy of the entire electromagnetic spectrum travels at the same speed in a vacuum. Specific frequency, energy or wavelength ranges of the electromagnetic spectrum are not required. However, the relative positions of the different bands, including the colors of visible light, are important (e.g., ultraviolet has more energy than microwaves). Radiant energy exhibits wave behaviors including reflection, refraction, absorption, superposition and diffraction, depending in part on the nature of the medium. For opaque objects (e.g., paper, a chair, an apple), little if any radiant energy is transmitted into the new material. However the radiant energy can be absorbed, usually increasing the thermal energy of the object and/or the radiant energy can be reflected. For rough objects, the reflection in all directions forms a diffuse reflection and for smooth shiny objects, reflections can result in clear images. Transparent materials transmit most of the energy through the material but smaller amounts of energy may be absorbed or reflected.  Changes in the observed frequency and wavelength of a wave can occur if the wave source and the observer are moving relative to each other. When the source and the observer are moving toward each other, the wavelength is shorter and the observed frequency is higher; when the source and the observer are moving away from each other, the wavelength is longer and the observed frequency is lower. This phenomenon is called the Doppler shift and can be explained using diagrams. This phenomenon is important to current understanding of how the universe was formed and will be applied in later sections of this course. Calculations to measure the apparent change in frequency or wavelength are not appropriate for this course. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Thermal energy**  In middle school, thermal energy is introduced as the energy of movement of the particles that make up matter. Processes of heat transfer, including conduction, convection and radiation, are studied. In other sections of this course, the role of thermal energy during heating, cooling and phase changes is explored conceptually and graphically. In this course, rates of thermal energy transfer and thermal equilibrium are introduced.  Thermal conductivity depends on the rate at which thermal energy is transferred from one end of a material to another. Thermal conductors have a high rate of thermal energy transfer and thermal insulators have a slow rate of thermal energy transfer. The rate at which thermal radiation is absorbed or emitted by a system depends on its temperature, color, texture and exposed surface area. All other things being equal, in a given amount of time, black rough surfaces absorb more thermal energy than smooth white surfaces. An object or system is continually absorbing and emitting thermal radiation. If the object or system absorbs more thermal energy than it emits and there is no change in phase, the temperature increases. If the object or system emits more thermal energy than is absorbed and there is no change in phase, the temperature decreases. For an object or system in thermal equilibrium, the amount of thermal energy absorbed is equal to the amount of thermal energy emitted; therefore, the temperature remains constant. In chemistry, changes in thermal energy are quantified for substances that change their temperature. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Electricity**   * Movement of electrons * Current * Electric potential (voltage) * Resistors and transfer of energy   In earlier grades, these concepts were introduced: electrical conductors and insulators; and a complete loop is needed for an electrical circuit that may be parallel or in a series. In this course, circuits are explained by the flow of electrons, and current; voltage and resistance are introduced conceptually to explain what was observed in middle school. The differences between electrical conductors and insulators can be explained by how freely the electrons flow throughout the material due to how firmly electrons are held by the nucleus.  By convention, electric current is the rate at which positive charge flows in a circuit. In reality, it is the negatively charged electrons that are actually moving. Current is measured in amperes (A), which is equal to one coulomb of charge per second (C/s). In an electric circuit, the power source supplies the electrons already in the circuit with electric potential energy by doing work to separate opposite charges. For a battery, the energy is provided by a chemical reaction that separates charges on the positive and negative sides of the battery. This separation of charge is what causes the electrons to flow in the circuit. These electrons then transfer energy to other objects and transform electrical energy into other forms (e.g., light, sound, heat) in the resistors. Current continues to flow, even after the electrons transfer their energy. Resistors oppose the rate of charge flow in the circuit. The potential difference or voltage across an energy source is a measure of potential energy in Joules supplied to each coulomb of charge. The volt (V) is the unit of potential difference and is equal to one Joule of energy per coulomb of charge (J/C). Potential difference across the circuit is a property of the energy source and does not depend upon the devices in the circuit. These concepts can be used to explain why current will increase as the potential difference increases and as the resistance decreases. Experiments, investigations and testing (3-D or virtual) must be used to construct a variety of circuits, and measure and compare the potential difference (voltage) and current. Electricity concepts are dealt with conceptually in this course. Calculations with circuits will be addressed in the physics syllabus. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Forces and Motion:**  **Motion**   * Introduction to one-dimensional vectors * Displacement, velocity (constant, average and instantaneous) and   acceleration   * Interpreting position vs. time and velocity vs. time graphs   The motion of an object depends on the observer’s frame of reference and is described in terms of distance, position, displacement, speed, velocity, acceleration and time. Position, displacement, velocity and acceleration are all vector properties (magnitude and direction). All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion. The relative nature of motion will be addressed conceptually, not mathematically. Non-inertial reference frames are excluded. Motion diagrams can be drawn and interpreted to represent the position and velocity of an object. Showing the acceleration on motion diagrams will be reserved for physics.  The displacement or change in position of an object is a vector quantity that can be calculated by subtracting the initial position from the final position (*Δ****x*** *=* ***xf*** *–* ***xi***)*.* Displacement can be positive or negative depending upon the direction of motion. Displacement is not always equal to the distance travelled. Examples should be given where the distance is not the same as the displacement.  Velocity is a vector property that represents the rate at which position changes. Average velocity can be calculated by dividing displacement (change in position) by the elapsed time (***vavg*** *= (****xf*** *–* ***xi****)/(tf – ti)*). Velocity may be positive or negative depending upon the direction of motion and is not always equal to the speed. Provide examples of when the average speed is not the same as the average velocity. Objects that move with constant velocity have the same displacement for each successive time interval. While speeding up or slowing down and/or changing direction, the velocity of an object changes continuously, from instant to instant. The speed of an object at any instant (clock reading) is called instantaneous speed. An object may not travel at this instantaneous speed for any period of time or cover any distance with that particular speed, especially if the speed is continually changing.  Acceleration is a vector property that represents the rate at which velocity changes. Average acceleration can be calculated by dividing the change in velocity divided by elapsed time (***aavg*** *= (****vf*** *–* ***vi****)/(tf – ti))*. At this grade level, it should be noted that acceleration can be positive or negative, but specifics about what kind of motions produce positive or negative accelerations will be addressed in the physics syllabus. The word “deceleration” should not be used because students tend to associate a negative sign of acceleration only with slowing down. Objects that have no acceleration can either be standing still or be moving with constant velocity (speed and direction). Constant acceleration occurs when the change in an object’s instantaneous velocity is the same for equal successive time intervals.  Motion can be represented by position vs. time and velocity vs. time graphs. Specifics about the speed, direction and change in motion can be determined by interpreting such graphs. For physical science, graphs will be limited to positive x-values and show only uniform motion involving constant velocity or constant acceleration. Motion must be investigated by collecting and analyzing data in the laboratory. Technology can enhance motion exploration and investigation through video analysis, the use of motion detectors and graphing data for analysis.  Objects that move with constant velocity and have no acceleration form a straight line (not necessarily horizontal) on a position vs. time graph. Objects that are at rest will form a straight horizontal line on a position vs. time graph. Objects that are accelerating will show a curved line on a position vs. time graph. Velocity can be calculated by determining the slope of a position vs. time graph. Positive slopes on position vs. time graphs indicate motion in a positive direction. Negative slopes on position vs. time graphs indicate motion in a negative direction. While it is important that students can construct graphs by hand, computer graphing programs or graphing calculators also can be used so more time can be spent on graph interpretation and analysis.  Constant acceleration is represented by a straight line (not necessarily horizontal) on a velocity vs. time graph. Objects that have no acceleration (at rest or moving at constant velocity) will have a straight horizontal line for a velocity vs. time graph. Average acceleration can be by determining the slope of a velocity vs. time graph. The details about motion graphs should not be taught as rules to memorize, but rather as generalizations that can be developed from interpreting the graphs. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Forces**   * Force diagrams * Types of forces (gravity, friction, normal, tension) * Field model for forces at a distance   Force is a vector quantity, having both magnitude and direction. The (SI) unit of force is a Newton. One Newton of net force will cause a 1 kg object to experience an acceleration of 1 m/s2. A Newton also can be represented as kg·m/s2. The opportunity to measure force in the lab must be provided (e.g., with a spring scale or a force probe). Normal forces and tension forces are introduced conceptually at this level. These forces and other forces are introduced in prior grades (friction, drag, contact, gravitational, electric and magnetic) and can be used as examples of forces that affect motion. Gravitational force (weight) can be calculated from mass, but all other forces will only be quantified from force diagrams that were introduced in middle school. In physical science, only forces in one dimension (positive and negative) will be addressed. The net force can be determined by one-dimensional vector addition. More quantitative study of friction forces, universal gravitational forces, elastic forces and electrical forces will be addressed in the physics syllabus.  Friction is a force that opposes sliding between two surfaces. For surfaces that are sliding relative to each other, the force on an object always points in a direction opposite to the relative motion of the object. In physical science, friction will only be calculated from force diagrams. Equations for static and kinetic friction are found in the physics syllabus.  A normal force exists between two solid objects when their surfaces are pressed together due to other forces acting on one or both objects (e.g., a solid sitting on or sliding across a table, a magnet attached to a refrigerator). A normal force is always a push directed at right angles from the surfaces of the interacting objects. A tension force occurs when a non-slack rope, wire, cord or similar device pulls on another object. The tension force always points in the direction of the pull.  In middle school, the concept of a field as a region of space that surrounds objects with the appropriate property (mass for gravitational fields, charge for electric fields, a magnetic object for magnetic fields) was introduced to explain gravitational, magnetic and electrical forces that occur over a distance. The field concept is further developed in physical science. The stronger the field, the greater the force exerted on objects placed in the field. The field of an object is always there, even if the object is not interacting with anything else. The gravitational force (weight) of an object is proportional to its mass. Weight, ***Fg,*** can be calculated from the equation ***Fg*** *= m* ***g***, where ***g*** is the gravitational field strength of an object which is equal to *9.8 N/kg (m/s2)* on the surface of Earth. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **The Universe**   * History of the universe * Galaxy formation * Stars * Formation; stages of evolution * Fusion in stars   ***History of the Universe***  The Big Bang Model is a broadly accepted theory for the origin and evolution of our universe. It postulates that 12 to 14 billion years ago, the portion of the universe seen today was only a few millimeters across (NASA).  According to the “big bang” theory, the contents of the known universe expanded explosively into existence from a hot, dense state 13.7 billion years ago (NAEP 2009). After the big bang, the universe expanded quickly (and continues to expand) and then cooled down enough for atoms to form. Gravity pulled the atoms together into gas clouds that eventually became stars, which comprise young galaxies. Foundations for the big bang model can be included to introduce the supporting evidence for the expansion of the known universe (e.g., Hubble’s law and red shift or cosmic microwave background radiation). A discussion of Hubble’s law and red shift is found in the *Galaxy formation* section, below.  Technology provides the basis for many new discoveries related to space and the universe. Visual, radio and x-ray telescopes collect information from across the entire electromagnetic spectrum; computers are used to manage data and complicated computations; space probes send back data and materials from remote parts of the solar system; and accelerators provide subatomic particle energies that simulate conditions in the stars and in the early history of the universe before stars formed.  ***Galaxy formation***  A galaxy is a group of billions of individual stars, star systems, star clusters, dust and gas bound together by gravity. There are billions of galaxies in the universe, and they are classified by size and shape. The Milky Way is a spiral galaxy. It has more than 100 billion stars and a diameter of more than 100,000 light years. At the center of the Milky Way is a bulge of stars, from which are spiral arms of gas, dust and most of the young stars. The solar system is part of the Milky Way galaxy.  Hubble’s law states that galaxies that are farther away have a greater red shift, so the speed at which a galaxy is moving away is proportional to its distance from the Earth. Red shift is a phenomenon due to Doppler shifting, so the shift of light from a galaxy to the red end of the spectrum indicates that the galaxy and the observer are moving farther away from one another. Doppler shifting also is found in the *Energy and Waves* section of this course.  ***Stars***  Early in the formation of the universe, stars coalesced out of clouds of hydrogen and helium and clumped together by gravitational attraction into galaxies. When heated to a sufficiently high temperature by gravitational attraction, stars begin nuclear reactions, which convert matter to energy and fuse the lighter elements into heavier ones. These and other fusion processes in stars have led to the formation of all the other elements. (NAEP 2009). All of the elements, except for hydrogen and helium, originated from the nuclear fusion reactions of stars (College Board Standards for College Success, 2009).  Stars are classified by their color, size, luminosity and mass. A Hertzprung-Russell diagram must be used to estimate the sizes of stars and predict how stars will evolve. Most stars fall on the main sequence of the H-R diagram, a diagonal band running from the bright hot stars on the upper left to the dim cool stars on the lower right.  A star’s mass determines the star’s place on the main sequence and how long it will stay there. Patterns of stellar evolution are based on the mass of the star. Stars begin to collapse as the core energy dissipates. Nuclear reactions outside the core cause expansion of the star, eventually leading to the collapse of the star.  **Note:** Names of stars and naming the evolutionary stage of a star from memory will not be assessed. The emphasis is on the interpretation of data (using diagrams and charts) and the criteria and processes needed to make those determinations. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **High School**  **Biology** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Course Description:**  Biology is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.  This course investigates the composition, diversity, complexity and interconnectedness of life on Earth. Fundamental concepts of heredity and evolution provide a framework through inquiry-based instruction to explore the living world, the physical environment and the interactions within and between them.  Students engage in investigations to understand and explain the behavior of living things in a variety of scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. | | | | | |
| **Heredity**   * Cellular genetics * Structure and function of DNA in cells * Genetic mechanisms and inheritance * Mutations * Modern genetics   Building on knowledge from elementary school (plants and animals have life cycles and offspring resemble their parents) and knowledge from middle school (reproduction, Mendelian Genetics, inherited traits and diversity of species), this topic focuses on the explanation of genetic patterns of inheritance. In middle school, students learn that living things are a result of one or two parents, and traits are passed on to the next generation through both asexual and sexual reproduction. In addition, they learn that traits are defined by instructions encoded in many discrete genes and that a gene may come in more than one form called alleles.  At the high school level, the explanation of genes is expanded to include the following concepts:   * Life is specified by genomes. Each organism has a genome that contains all of the biological information needed to build and maintain a living example of that organism. The biological information contained in a genome is encoded in its deoxyribonucleic acid (DNA) and is divided into discrete units called genes. * Genes are segments of DNA molecules. The sequence of DNA bases in a chromosome determines the sequence of amino acids in a protein. Inserting, deleting or substituting segments of DNA molecules can alter genes. * An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm or have little or no effect on the offspring’s success in its environments. * Gene mutations (when they occur in gametes) can be passed on to offspring. * Genes code for protein. The sequence of DNA bases in a chromosome determines the sequence of amino acids in a protein. * “The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. Different genes are active in different types of cells, influenced by the cell’s environment and past history.” (AAAS)   In high school biology, Mendel’s laws of inheritance (introduced in grade 8) are interwoven with current knowledge of DNA and chromosome structure and function to build toward basic knowledge of modern genetics. Sorting and recombination of genes in sexual reproduction and meiosis specifically result in a variance in traits of the offspring of any two parents and explicitly connect the knowledge to evolution.  The gene interactions described in middle school were limited primarily to dominance and co-dominance traits. In high school genetic mechanisms, both classical and modern including incomplete dominance, sex-linked traits, goodness of fit test (Chi-square) and dihybrid crosses are investigated through real-world examples. Genes that affect more than one trait (pleiotropy), traits affected by more than one gene (epistasis) and polygenetic traits can be introduced using simple real-world examples.  Additionally, genes that modify or regulate the expression of another gene should be included in explorations at the high school level. Dihybrid crosses can be used to explore linkage groups. Modern genetics techniques, such as cloning must be explored in this unit.  It is imperative that the technological developments that lead to the current knowledge of heredity be included in the study of heredity. For example, the development of the model for DNA structure was the result of the use of technology and the studies and ideas of many scientists. Watson and Crick developed the final model, but did not do the original studies. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Evolution**   * Mechanisms * Natural selection * Mutation * Genetic drift * Gene flow (immigration, emigration) * Sexual selection * History of life on Earth * Diversity of Life * Speciation and biological classification based on molecular evidence * Variation of organisms within a species due to population genetics and gene frequency   At the elementary school level, evolution concepts include the relationship between organisms and the environment, parent and offspring, and an introduction to the fossil record and extinction. At the middle school level, concepts include biodiversity (as part of biomes) and speciation, further exploration of the fossil record and Earth history, changing environmental conditions (abiotic factors), natural selection and biological evolution.  Biological evolution explains the natural origins for the diversity of life. Emphasis shifts from thinking in terms of selection of individuals with a particular trait to changing proportions of a trait in populations. The study of evolution must include Modern Synthesis, the unification of genetics and evolution and historical perspectives of evolutionary theory. The study of evolution must include gene flow, mutation, speciation, natural selection, genetic drift, sexual selection and Hardy Weinberg’s law.  The basic concept of biological evolution is that the Earth’s present-day species descended from earlier, common ancestral species. At the high school level, the term natural selection is used to describe the process by which traits become more or less common in a population due to consistent environmental effects upon the survival or reproduction of the individual with the trait. Mathematical reasoning must be applied to solve problems, (e.g., use Hardy Weinberg’s law to explain gene frequency patterns in a population).  Modern ideas about evolution provide a natural explanation for the diversity of life on Earth as represented in the fossil record, in the similarities of existing species and in modern molecular evidence. From a long-term perspective, evolution is the descent with modification of different lineages from common ancestors.  Different phenotypes result from new combinations of existing genes or from mutations of genes in reproductive cells. At the high school level, the expectation is to combine grade 8 knowledge with explanation of the internal structure and function of chromosomes. Natural selection works on the phenotype.  Populations evolve over time. Evolution is the consequence of the interactions of:  1. The potential for a population to increase its numbers;  2. The genetic variability of offspring due to mutation and recombination of genes;  3. A finite supply of the resources required for life; and  4. The differential survival and reproduction of individuals with the specific phenotype.  Mutations are described in the content elaboration for Heredity. Apply the knowledge of mutation and genetic drift to real-world examples.  Recent molecular-sequence data generally, but not always, support earlier hypotheses regarding lineages of organisms based upon morphological comparisons.  Heritable characteristics influence how likely an organism is to survive and reproduce in a particular environment. When an environment changes, the survival value of inherited characteristics may change. This may or may not cause a change in species that inhabit the environment. Formulate and revise explanations for gene flow and sexual selection based on real-world problems. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Diversity and Interdependence of Life**   * Classification systems are frameworks created by scientists for describing the vast diversity of organisms indicating the degree of relatedness between organisms. * Ecosystems * Homeostasis * Carrying capacity * Equilibrium and disequilibrium   Building on knowledge from elementary school (interactions of organisms within their environment and the law of conservation of matter and energy, food webs) and from middle school (flow of energy through organisms, biomes and biogeochemical cycles), this topic focuses on the study of diversity and similarity at the molecular level of organisms. Additionally the effects of physical/chemical constraints on all biological relationships and systems are investigated.  The great diversity of organisms and ecological niches they occupy result from more than 3.5 billion years of evolution. Some ecosystems can be reasonably persistent over hundreds or thousands of years. Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change as geological or biological conditions vary. Misconceptions about population growth capacity, interspecies and intra-species competition for resources, and what occurs when a species immigrates to or emigrates from ecosystems are included in this topic. Technology must be used to access real-time/authentic data to study population changes and growth in specific locations.  Classification systems are frameworks developed by scientists for describing the diversity of organisms, indicating the degree of relatedness between organisms. Recent molecular-sequence data generally support earlier hypotheses regarding lineages of organisms based upon morphological comparisons. Both morphological comparisons and molecular evidence must be used to describe biodiversity (cladograms can be used to address this).  Organisms transform energy (flow of energy) and matter (cycles of matter) as they survive and reproduce. The cycling of matter and flow of energy occurs at all levels of biological organization, from molecules to ecosystems. At the high school level, the concept of energy flow as unidirectional in ecosystems is explored.  Mathematical graphing and algebraic knowledge (at the high school level) must be used to explain concepts of carrying capacity and homeostasis within biomes. Use real-time data to investigate population changes that occur locally or regionally. Mathematical models can include exponential growth model and the logistic growth model. The simplest version of the logistic growth model is *dN/dt = rN (K-N/K)*; the only new variable added to the exponential model is K for carrying capacity.  **Note 1:** Exponential growth equation in simplest form, change in population size *N* per unit time *t* is a product of *r* (the per capita reproductive rate) and *N* (population size).  **Note 2:** Carrying capacity is defined as the population equilibrium sized when births and deaths are equal; hence dN/dt = zero.  **Note 3:** Constructing food webs/food chains to show interactions between organisms within ecosystems was covered in upper elementary school and middle school; constructing them as a way to demonstrate content knowledge is not appropriate for this grade. Students may use these diagrams to help explain real-world relationships or events within an ecosystem, but not to identify simple trophic levels, consumers, producers, predator-prey and symbiotic relations. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Cells**   * Cell structure and function * Structure, function and interrelatedness of cell organelles * Eukaryotic cells and prokaryotic cells * Cellular processes * Characteristics of life regulated by cellular processes * Photosynthesis, chemosynthesis, cellular respiration * Cell division and differentiation   Building on knowledge from middle school (cell theory), this topic focuses on the cell as a system itself (single-celled organism) and as part of larger systems (multicellular organism), sometimes as part of a multicellular organism, always as part of an ecosystem. The cell is a system that conducts a variety of functions associated with life. Details of cellular processes such as photosynthesis, chemosynthesis, cellular respiration, cell division and differentiation are studied at this grade level. Additionally, cellular organelles studied are cytoskeleton, Golgi complex and endoplasmic reticulum.  From about 4 billion years ago to about 2 billion years ago, only simple, single-celled microorganisms are found in the fossil record. Once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved.  Every cell is covered by a membrane that controls what can enter and leave the cell. In all but quite primitive cells, a complex network of proteins provides organization and shape. Within the cell are specialized parts for the transport of materials, energy transformation, protein building, waste disposal, information feedback and movement. In addition to these basic cellular functions, most cells in multicellular organisms perform some specific functions that others do not.  A living cell is composed of a small number of elements, mainly carbon, hydrogen, nitrogen, oxygen, phosphorous and sulfur. Carbon, because of its small size and four available bonding electrons, can join to other carbon atoms in chains and rings to form large and complex molecules. The essential functions of cells involve chemical reactions that involve water and carbohydrates, proteins, lipids and nucleic acids. A special group of proteins, enzymes, enables chemical reactions to occur within living systems.  Cell functions are regulated. Complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Most cells function within a narrow range of temperature and pH. At very low temperatures, reaction rates are slow. High temperatures and/or extremes of pH can irreversibly change the structure of most protein molecules. Even small changes in pH can alter how molecules interact. The sequence of DNA bases on a chromosome determines the sequence of amino acids in a protein. Proteins catalyze most chemical reactions in cells. Protein molecules are long, usually folded chains made from combinations of the 20 typical amino-acid sub-units found in the cell. The function of each protein molecule depends on its specific sequence of amino acids and the shape the chain takes as a result of that sequence. **Note 1:** The idea that protein molecules assembled by cells conduct the work that goes on inside and outside the cells in an organism can be learned without going into the biochemical details. It is sufficient for students to know that the molecules involved are different configurations of a few amino acids and that the different shapes of the molecules influence what they do.  **Note 2:** The concept of the cell and its parts. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **High School**  **Chemistry** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Course Description:**  Chemistry is a high school level course that satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.  This course introduces students to key concepts and theories that provide a foundation for further study in other sciences as well as advanced science disciplines. Chemistry comprises a systematic study of the *predictive* physical interactions of matter and subsequent events that occur in the natural world. The study of matter through the exploration of classification, its structure and its interactions is how this course is organized.  Investigations are used to understand and explain the behavior of matter in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. An understanding of leading theories and how they have informed current knowledge prepares students with higher order cognitive capabilities of evaluation, prediction and application. | | | | | |
| **Structure and Properties of Matter**   * Atomic structure * Evolution of atomic models/theory * Electrons * Electron configurations   ***Atomic structure***  The physical science syllabus includes properties and locations of protons, neutrons and electrons, atomic number, mass number, cations and anions, isotopes and the strong nuclear force that hold the nucleus together. In this course, the historical development of the atom and the positions of electrons are explored in more detail.  Atomic models are constructed to explain experimental evidence and make predictions. The changes in the atomic model over time exemplify how scientific knowledge changes as new evidence emerges, and how technological advancements like electricity extend the boundaries of scientific knowledge. Thompson’s study of electrical discharges in cathode-ray tubes led to the discovery of the electron and the development of the plum pudding model of the atom. Rutherford’s experiment, in which he bombarded gold foil with α-particles, led to the discovery that most of the atom consists of empty space with a relatively small, positively charged nucleus. Bohr used data from atomic spectra to propose a planetary model of the atom in which electrons orbit the nucleus, like planets around the sun. Later, Schrödinger used the idea that electrons travel in waves to develop a model in which electrons travel randomly in regions of space called orbitals (quantum mechanical model).  Based on the quantum mechanical model, it is not possible to predict exactly where electrons are located but there is a region of space surrounding the nucleus in which there is a high probability of finding an electron (electron cloud or orbital). Data from atomic spectra (emission and absorption) gives evidence that electrons can only exist at certain discrete energy levels and not at energies between these levels. Atoms are usually in the ground state where the electrons occupy orbitals with the lowest available energy. However, the atom can become excited when the electrons absorb a photon with the precise amount of energy (indicated by the frequency of the photon) to move to an orbital with higher energy. Any photon without this precise amount of energy will be ignored by the electron. The atom exists in the excited state for a very short amount of time. When an electron drops back down to the lower energy level, it emits a photon that has energy equal to the energy difference between the levels. The amount of energy is indicated by the frequency of the light that is given off and can be measured. Each element has a unique emission and absorption spectrum due to its unique electron configuration and specific electron energy jumps that are possible for that element. Being aware of the quantum mechanical model as the currently accepted model for the atom is important for science literacy because it explains and predicts subatomic interactions, but details should be reserved for more advanced study.  Electron energy levels consist of sublevels (s, p, d and f), each with a characteristic number and shape of orbitals. The shapes of d and f orbitals will not be assessed in high school. Orbital diagrams and electron configurations can be constructed to show the location of the electrons in an atom using established rules. However, the names of these rules will not be assessed. Valence electrons are responsible for most of the chemical properties of elements. In this course, electron configurations (extended and noble gas notation) and orbital diagrams can be shown for any element in the first three periods.  Although the quantum mechanical model of the atom explains the most experimental evidence, other models can still be helpful. Thinking of atoms as indivisible spheres is useful in explaining many physical properties of substances, such as the state (solid, liquid or gas) of a substance at room temperature. Bohr’s planetary model is useful to explain and predict periodic trends in the properties of elements.  **Note:** Quantum numbers and equations of de Broglie, Schrödinger and Plank are beyond the scope of this course. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Periodic table**   * Properties * Trends   In the physical science syllabus, elements are placed in order of increasing atomic number in the periodic table such that elements with similar properties are placed in the same column. How the periodic table is divided into groups, families, periods, metals, nonmetals and metalloids is also in the physical science syllabus. In chemistry, with more information about the electron configuration of elements, similarities in the configuration of the valence electrons for a particular group can be observed. The electron configuration of an atom can be written from the position on the periodic table. The repeating pattern in the electron configurations for elements on the periodic table explain many of the trends in the properties observed. Atomic theory and bonding must be used to explain trends in properties across periods or down columns including atomic radii, ionic radii, first ionization energies, electronegativities and whether the element is a solid or gas at room temperature. Additional ionization energies, electron affinities and periodic properties of the transition elements, lanthanide and actinide series is reserved for more advanced study**.** |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Intramolecular chemical bonding**   * Ionic * Polar/covalent   In the physical science syllabus, atoms with unpaired electrons tend to form ionic and covalent bonds with other atoms forming molecules, ionic lattices or network covalent structures. In this course, electron configurations, electronegativity values and energy considerations will be applied to bonding and the properties of materials with different types of bonding.  Atoms of many elements are more stable as they are bonded to other atoms. In such cases, as atoms bond, energy is released to the surroundings resulting in a system with lower energy. An atom’s electron configuration, particularly the valence elections, determines how an atom interacts with other atoms. Molecules, ionic lattices and network covalent structures have different, yet predictable, properties that depend on the identity of the elements and the types of bonds formed.  Differences in electronegativity values can be used to predict where a bond fits on the continuum between ionic and covalent bonds. The polarity of a bond depends on the electronegativity difference and the distance between the atoms (bond length). Polar covalent bonds are introduced as an intermediary between ionic and pure covalent bonds. The concept of metallic bonding also is introduced to explain many of the properties of metals (e.g., conductivity). Since most compounds contain multiple bonds, a substance may contain more than one type of bond. Compounds containing carbon are an important example of bonding, since carbon atoms can bond together and with other atoms, especially hydrogen, oxygen, nitrogen and sulfur to form chains, rings and branching networks that are present in a variety of compounds, including synthetic polymers, fossil fuels and the large molecules essential to life. Detailed study of the structure of molecules responsible for life is reserved for more advanced courses. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Representing compounds**   * Formula writing * Nomenclature * Models and shapes (Lewis structures, ball and stick, molecular geometries)   Using the periodic table, formulas of ionic compounds containing specific elements can be predicted. This can include ionic compounds made up of elements from groups 1, 2, 17, hydrogen and oxygen and polyatomic ions if given the formula and charge of the polyatomic ion. Given the formula, a compound can be named using conventional systems that include Greek prefixes and Roman numerals where appropriate. Given the name of an ionic or covalent substance, formulas can be written.  Many different models can be used to represent compounds including chemical formulas, Lewis structures, and ball and stick models. These models can be used to visualize atoms and molecules and to predict the properties of substances. Each type of representation provides unique information about the compound. Different representations are better suited for particular substances. Lewis structures can be drawn to represent covalent compounds using a simple set of rules, and can be combined with valence shell electron pair repulsion (VSEPR) theory to predict the three-dimensional electron pair and molecular geometry of compounds. Lewis structures and molecular geometries will only be constructed for the following combination of elements: hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur and the halogens. Organic nomenclature is reserved for more advanced courses. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Quantifying matter**  In earlier grades, properties of materials were quantified with measurements that were always associated with some error. In this course, scientific protocols for quantifying the properties of matter accurately and precisely are studied. Using metric measuring systems, significant digits or figures, scientific notation, error analysis and dimensional analysis are vital to scientific communication.  There are three domains of magnitude in size and time: the macroscopic (human) domain, the cosmic domain and the submicroscopic (atomic and subatomic) domain. Measurements in the cosmic domain and submicroscopic domains require complex instruments and/or procedures.  Matter can be quantified in a way that macroscopic properties such as mass can reflect the number of particles present. Elemental samples are a mixture of several isotopes with different masses. The atomic mass of an element is calculated given the mass and relative abundance of each isotope of the element as it exists in nature. Because the mass of an atom is very small, the mole is used to translate between the atomic and macroscopic levels. A mole is used as a counting number, like a dozen. It is equal to the number of particles in exactly 12 grams of carbon – 12 atoms. The mass of one mole of a substance is equal to its formula mass in grams. The formula mass for a substance can be used in conjunction with Avogadro’s number and the density of a substance to convert between mass, moles, volume and number of particles of a sample. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Phases of matter**  In middle school, solids, liquids and gases were explored in relation to the spacing of the particles, motion of the particles and strength of attraction between the particles that make up the substance. In this course, plasmas and Bose-Einstein condensates also are included. Plasmas occur when gases have so much energy that the electrons are stripped away; therefore, they are electrically charged. In Bose-Einstein condensation the atoms, when subjected to temperatures a few billionths of a degree above absolute zero, all coalesce to lose individual identity and become a “super atom.” Just as plasmas are super-hot atoms, Bose-Einstein condensates are the opposite – super-cold atoms (see **Note**). The forces of attraction between particles that determine whether a substance is a solid, liquid or gas at room temperature are addressed in greater detail with intermolecular chemical bonding later in the course.  **Note:** The advancement of technology makes it possible to extend the boundaries of current knowledge and understanding. Consequently, Bose-Einstein condensates were only recently created in the laboratory (1995), although predicted more than 80 years ago. Detailed instruction of Bose-Einstein condensates or plasmas is not required at this grade level. This information is strictly for recognition that new discoveries are continually occurring, extending the realm of current understanding in science. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Intermolecular Chemical Bonding**   * Intermolecular chemical bonding * Types and strengths * Implications for properties of substances * Melting and boiling point * Solubility * Vapor pressure   In middle school, the concept of attractions between separate particles that hold molecules together in liquids and solids was introduced. These forces, called intermolecular attractions, are addressed in more detail in chemistry. Intermolecular attractions are generally weak when compared to intramolecular bonds, but span a wide range of strengths. The composition of a substance and the shape and polarity of a molecule are particularly important in determining the type and strength of bonding and intermolecular interactions. Types of intermolecular attractions include London dispersion forces (present between all molecules), dipole-dipole forces (present between polar molecules) and hydrogen bonding (a special case of dipole-dipole where hydrogen is bonded to a highly electronegative atom such as fluorine, oxygen or nitrogen), each with its own characteristic relative strengths.  The configuration of atoms in a molecule determines the strength of the forces (bonds or intermolecular forces) between the particles and therefore the physical properties (e.g., melting point, boiling point, solubility, vapor pressure) of a material. For a given substance, the average kinetic energy (and therefore the temperature) needed for a change of state to occur depends upon the strength of the intermolecular forces between the particles. Therefore, the melting point and boiling point depend upon the amount of energy that is needed to overcome the attractions between the particles. Substances that have strong intermolecular forces or are made up of three-dimensional networks of ionic or covalent bonds tend to be solids at room temperature and have high melting and boiling points. Nonpolar organic molecules are held together by weak London dispersion forces. However, substances with longer chains provide more opportunities for these attractions and tend to have higher melting and boiling points. Increased branching of organic molecules interferes with the intermolecular attractions that lead to lower melting and boiling points.  Substances will have a greater solubility when dissolving in a solvent with similar intermolecular forces. If the substances have different intermolecular forces, they are more likely to interact with themselves than the other substance and remain separated from each other. Water is a polar molecule and it is often used as a solvent since most ionic and polar covalent substances will dissolve in it. In order for an ionic substance to dissolve in water, the attractive forces between the ions must be overcome by the dipole-dipole interactions with the water. Dissolving of a solute in water is an example of a process that is difficult to classify as a chemical or physical change and it is not appropriate to have students classify it one way or another.  Evaporation occurs when the particles with enough kinetic energy to overcome the attractive forces separate from the rest of the sample to become a gas. The pressure of these particles is called vapor pressure. Vapor pressure increases with temperature. Particles with larger intermolecular forces have lower vapor pressures at a given temperature since the particles require more energy to overcome the attractive forces between them. Molecular substances often evaporate more due to the weak attractions between the particles and can often be detected by their odor. Ionic or network covalent substances have stronger forces and are not as likely to volatilize. These substances often have little if any odor. Liquids boil when their vapor pressure is equal to atmospheric pressure.  In solid water, there is a network of hydrogen bonds between the particles that gives it an open structure. This is why water expands as it freezes and why solid water has a lower density than liquid water. This has important implications for life (e.g., ice floating on water acts as an insulator in bodies of water to keep the temperature of the rest of the water above freezing.) |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Interaction of Matter**  **Chemical reactions**   * Types of reactions * Kinetics * Energy * Equilibrium * Acids/bases   In the physical science syllabus, coefficients are introduced to balance simple equations. Other representations including Lewis structures and three-dimensional models also were used and manipulated to demonstrate the conservation of matter in chemical reactions. In this course, more complex reactions will be studied, classified and represented with chemical equations and three-dimensional models. Classifying reactions into types can be a helpful organizational tool in recognizing patterns of what may happen when two substances are mixed (see **Note**). Some general types of chemical reactions are oxidation/reduction, synthesis, decomposition, single-replacement, double replacement (including precipitation reactions and some acid-base neutralizations) and combustion reactions. Some reactions can fit into more than one category. For example, a single replacement reaction also can be classified as an oxidation/reduction reaction. Identification of reactions involving oxidation and reduction, as well as indicating what substance is being oxidized and what is being reduced, are appropriate in this course. However, balancing complex oxidation/reduction reactions will be reserved for more advanced study.  Organic molecules release energy when undergoing combustion reactions and are used to meet the energy needs of society (e.g., oil, gasoline, natural gas) and to provide the energy needs of biological organisms (e.g., cellular respiration). When a reaction between two ionic compounds in aqueous solution results in the formation of a precipitate or molecular compound, the reaction often occurs because the new ionic or covalent bonds are stronger than the original ion-dipole interactions of the ions in solution. Laboratory experiences (3-D or virtual) with different types of chemical reactions must be provided.  **Note:** Teachers should be aware that the common reaction classifications that are often used in high school chemistry courses often lead to misconceptions because they are not based on the actual chemistry, but on surface features that may be similar from one system to another (e.g., exchanging partners), even though the underlying chemistry is not the same. However, they may be useful in making predictions about what may happen when two substances are mixed.  Reactions occur when reacting particles collide in an appropriate orientation and with sufficient energy. Not all collisions are effective. Stable reactants require the input of energy, the activation energy, to initiate a reaction. A catalyst provides an alternate pathway for a reaction, usually with a lower activation energy. With this lower energy threshold, more collisions will have enough energy to result in a reaction. An enzyme is a large organic molecule that folds into a unique shape by forming intermolecular bonds with itself. The enzyme’s shape allows it to hold a substrate molecule in the proper orientation to result in an effective collision. The rate of a chemical reaction is the change in the amount of reactants or products in a specific period of time. Increasing the probability or effectiveness of the collisions between the particles increases the rate of the reaction. Therefore, changing the concentration of the reactants, the temperature or the pressure of gaseous reactants can change the reaction rate. Likewise, the collision theory can be applied to dissolving solids in a liquid solvent and can be used to explain why reactions are more likely to occur between reactants in the aqueous or gaseous state than between solids. The rate at which a substance dissolves should not be confused with the amount of solute that can dissolve in a given amount of solvent (solubility). Mathematical treatment of reaction rates are reserved for later study. Computer simulations can help visualize reactions from the perspective of the kinetic-molecular theory.  In middle school, the differences between potential and kinetic energy and the particle nature of thermal energy were introduced. For chemical systems, potential energy is in the form of chemical energy and kinetic energy is in the form of thermal energy. The total amount of chemical energy and/or thermal energy in a system is impossible to measure. However, the energy change of a system can be calculated from measurements (mass and change in temperature) from calorimetry experiments in the laboratory. Conservation of energy is an important component of calorimetry equations. Thermal energy is the energy of a system due to the movement (translational, vibrational and rotational) of its particles. The thermal energy of an object depends upon the amount of matter present (mass), temperature and chemical composition. Some materials require little energy to change their temperature and other materials require a great deal to change their temperature by the same amount. Specific heat is a measure of how much energy is needed to change the temperature of a specific mass of material a specific amount. Specific heat values can be used to calculate the thermal energy change, the temperature (initial, final or change in) or mass of a material in calorimetry. Water has a particularly high specific heat capacity, which is important in regulating Earth’s temperature.  As studied in middle school, chemical energy is the potential energy associated with chemical  systems. Chemical reactions involve valence electrons forming bonds to yield more stable products with lower energies. Energy is required to break interactions and bonds between the reactant atoms and energy is released when an interaction or bond is formed between the atoms in the products. Molecules with weak bonds (e.g., ATP) are less stable and tend to react to produce more stable products, releasing energy in the process. Generally, energy is transferred out of the system (exothermic) when the products have stronger bonds than the reactants and is transferred into the system (endothermic) when the reactants have stronger bonds than the products. Predictions of the energy requirements (endothermic or exothermic) of a reaction can be made given a table of bond energies. Graphic representations can be drawn and interpreted to represent the energy changes during a reaction, including the activation energy. The roles of energy and entropy in determining the spontaneity of chemical reactions are dealt with conceptually in this course. Avoid describing entropy as the amount of disorder since this leads to persistent misconceptions. Mathematical treatment of entropy and its influence on the spontaneity of reactions is reserved for advanced study.  All reactions are reversible to a degree and many reactions do not proceed completely toward products but appear to stop progressing before the reactants are all used up. At this point, the amounts of the reactants and the products appear to be constant and the reaction can be said to have reached dynamic equilibrium. In fact, the reaction has stopped because the rate of the reverse reaction is equal to the rate of the forward reaction so there is no apparent change in the reaction. If given a graph showing the concentration of the reactants and products over the time of reaction, the equilibrium concentrations and the time at which equilibrium was established can be determined. Some reactions appear to proceed only in one direction. In these cases, the reverse reaction can occur but is highly unlikely (e.g., combustion reactions). Such reactions usually release a large amount of energy and require a large input of energy to go in the reverse direction. If a chemical system at equilibrium is disturbed by a change in the conditions of the system (e.g., increase or decrease in the temperature, pressure on gaseous equilibrium systems, concentration of a reactant or product), then the equilibrium system will respond by shifting to a new equilibrium state, reducing the effect of the change (Le Chatelier’s Principle). If products are removed as they are formed during a reaction, then the equilibrium position of the system is forced to shift to favor the products. In this way, an otherwise unfavorable reaction can be made to occur. Mathematical treatment of equilibrium reactions is reserved for advanced study. Computer simulations can help visualize the progression of a reaction to dynamic equilibrium and the continuation of both the forward and reverse reactions after equilibrium has been attained.  Properties of acids and bases and the ranges of the pH scale were introduced in middle school. In chemistry, the structural features of molecules are explored to further understand acids and bases. Acids often result when hydrogen is covalently bonded to an electronegative element and is easily dissociated from the rest of the molecule to bind with water to form a hydronium ion (H3O+). The acidity of an aqueous solution can be expressed as pH, where pH can be calculated from the concentration of the hydronium ion. Bases are likely to dissociate in water to form a hydroxide ion. Acids can react with bases to form a salt and water. Such neutralization reactions can be studied quantitatively by performing titration experiments. Detailed instruction about the equilibrium of acids and bases and the concept of Brønsted-Lowry and Lewis acids and bases will not be assessed at this level. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Gas laws**   * Pressure, volume and temperature * Ideal gas law   The kinetic-molecular theory can be used to explain the macroscopic properties of gases (pressure, temperature and volume) through the motion and interactions of its particles. When one of the three properties is kept constant, the relationship between the other two properties can be quantified, described and explained using the kinetic-molecular theory. Real-world phenomena (e.g., why tire pressure increases in hot weather, why a hot air balloon rises) can be explained using this theory. Problems also can be solved involving the changes in temperature, pressure and volume of a gas. When solving gas problems, the Kelvin temperature scale must be used since only in this scale is the temperature directly proportional to the average kinetic energy. The Kelvin temperature is based on a scale that has its minimum temperature at absolute zero, a temperature at which all motion theoretically stops. Since equal volumes of gases at the same temperature and pressure contain an equal number of particles (Avogadro’s law), problems can be solved for an unchanging gaseous system using the ideal gas law (PV = nRT) where R is the ideal gas constant (e.g., represented in multiple formats, 8.31 Joules / (mole K). The specific names of the gas laws are not addressed in this course. Deviations from ideal gaseous behavior are reserved for more advanced study. Explore the relationships between the volume, temperature and pressure in the laboratory or through computer simulations or virtual experiments. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Stoichiometry**   * Molar calculations * Solutions * Limiting reagents   A stoichiometric calculation involves the conversion from the amount of one substance in a chemical reaction to the amount of another substance. The coefficients of the balanced equation indicate the ratios of the substances involved in the reaction in terms of both particles and moles. Once the number of moles of a substance is known, amounts can be changed to mass, volume of a gas, volume of solutions and/or number of particles. Molarity is a measure of the concentration of a solution that can be used in stoichiometric calculations. When performing a reaction in the lab, the experimental yield can be compared to the theoretical yield to calculate percent yield. The concept of limiting reagents is treated conceptually and not mathematically. Molality and Normality are concepts reserved for more advanced study. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Nuclear Reactions**   * Radioisotopes * Nuclear energy   The basics of nuclear forces, isotopes, radioactive decay, fission and fusion are addressed in the physical science syllabus. In chemistry, specific types of radioactive decay and using nuclear reactions as a source of energy are addressed. Radioactive decay can result in the release of different types of radiation (alpha, beta, gamma, positron) each with a characteristic mass, charge and potential to ionize and penetrate the material it strikes. Beta decay results from the decay of a neutron and positron decay results from the decay of a proton. When a radioisotope undergoes alpha, beta or positron decay, the resulting nucleus can be predicted and the balanced nuclear equation can be written.  Nuclear reactions, such as fission and fusion, are accompanied by large energy changes that are much greater than those that accompany chemical reactions. These nuclear reactions can theoretically be used as a controlled source of energy in a nuclear power plant. There are advantages and disadvantages of generating electricity from fission and fusion. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **High School**  **Environmental Science** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Course Desciption:**  Environmental science is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.  Environmental science incorporates biology, chemistry, physics and physical geology and introduces students to key concepts, principles and theories within environmental science.  Investigations are used to understand and explain the behavior of nature in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. It should be noted that there are classroom examples in the model curriculum that can be developed to meet multiple sections of the syllabus, so one well-planned, long-term project can be used to teach multiple topics. | | | | | |
| **Earth Systems: Interconnected Spheres of Earth**   * Biosphere * Evolution and adaptation in populations * Biodiversity * Ecosystems (equilibrium, species interactions, stability) * Population dynamics * Atmosphere * Atmospheric properties and currents * Lithosphere * Geologic events and processes * Hydrosphere * Oceanic currents and patterns (as they relate to climate) * Surface and ground water flow patterns and movement * Cryosphere * Movement of matter and energy through the hydrosphere, lithosphere, atmosphere and biosphere * Energy transformations on global, regional and local scales * Biogeochemical cycles * Ecosystems * Climate and weather   **Earth Systems: Interconnected Spheres of Earth Biosphere**   * Evolution and adaptation in populations * Biodiversity * Ecosystems (equilibrium, species interactions, stability) * Population dynamics   This topic builds upon both the physical science and biology courses as they relate to energy transfer and transformation, conservation of energy and matter, evolution, adaptation, biodiversity, population studies, and ecosystem composition and dynamics. In grades 6-8, geologic processes, biogeochemical cycles, climate, the composition and properties of the atmosphere, lithosphere and hydrosphere (including the hydrologic cycle) are studied.  The focus for this topic is on the connections and interactions between Earth’s spheres (the hydrosphere, atmosphere, biosphere and lithosphere). Both natural and human-made interactions must be studied. This includes an understanding of causes and effects of climate, global climate (including el Niño/la Niña patterns and trends) and changes in climate through Earth’s history, geologic events (e.g., a volcanic eruption or mass wasting) that impact Earth’s spheres, biogeochemical cycles and patterns, the effect of abiotic and biotic factors within an ecosystem, and the understanding that each of Earth’s spheres is part of the dynamic Earth system. Ground water and surface water velocities and patterns are included as the movement of water (either at the surface, in the atmosphere or beneath the surface) can be a mode of transmission of contamination. This builds upon previous hydrologic cycle studies in earlier grades. Geomorphology and topography are helpful in determining flow patterns and pathways for contamination.  The connections and interactions of energy and matter between Earth’s spheres must be researched and investigated using actual data. The emphasis is on the interconnectedness of Earth’s spheres and the understanding of the complex relationships between each, including both abiotic and biotic factors. One event, such as a petroleum release or a flood, can impact each sphere. Some impacts are long-term, others are short-term and most are a combination of both long- and short-term. It is important to use real, quantifiable data to study the interactions, patterns and cycles between Earth’s spheres. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Earth’s Resources**  Energy resources   * Renewable and nonrenewable energy sources and efficiency * Alternate energy sources and efficiency * Resource availability * Mining and resource extraction   Air and air pollution   * Primary and secondary contaminants * Greenhouse gases * Clean Air Act   Water and water pollution   * Potable water and water quality * Hypoxia, eutrophication * Clean Water Act * Point source and non-point source contamination   Soil and land   * Desertification * Mass wasting and erosion * Sediment contamination * Land use and land management (including food production, agriculture and zoning) * Solid and hazardous waste   Wildlife and wilderness   * Wildlife and wilderness management * Endangered species   This topic explores the availability of Earth’s resources, extraction of the resources, contamination problems, remediation techniques and the storage/disposal of the resources or by-products. Conservation, protection and sustainability of Earth’s resources also are included. This builds upon grades 6-8 within the Earth and Space Science strand (sections pertaining to energy and Earth’s resources) and the biology and physical science (in particular chemistry and energy topics) courses at the high school level.  To understand the effects that certain contaminants may have on the environment, scientific investigations and research must be conducted on a local, national and global level. Water, air, land, and biotic field and lab sampling/testing equipment and methods must be utilized with real-world application. Quantifiable field and/or lab data must be used to analyze and draw conclusions regarding air, water or land quality. Examples of types of water-quality testing include: hydraulic conductivity, suspended and dissolved solids, dissolved oxygen, biochemical oxygen demand, temperature, pH, fecal coliform and macro-invertebrate studies. Wetland or woodland delineations and analysis, land-use analysis and air monitoring (e.g., particulate matter sizes/amount) are all appropriate field study investigations. Comparative analysis of scientific field or lab data should be used to quantify the environmental quality or conditions. Local data also can be compared to national and international data.  The study of relevant, local problems can be a way to connect the classroom to the real world. Within Ohio, there are numerous environmental topics that can be investigated. Examples include wetland loss or mitigation, surface or ground water contamination (including sediment, chemical or thermal contamination), acid rain, septic system or sewage overflows/failures, landfill seepage, underground storage tank/pipe releases, deforestation, invasive species, air pollution (e.g., photochemical smog or particulate matter), soil loss/erosion or acid mine drainage.  At the advanced science level, renewable and nonrenewable energy resources topics investigate the effectiveness, risk and efficiency for differing types of energy resources at a local, state, national and global level. This builds upon grades 6-8 within both Earth and Space Science, and physical science at the high school level. Nuclear and geothermal energy are included in this topic.  Feasibility, availability, remediation and environmental cost are included in the extraction, storage, use and disposal of both abiotic and biotic resources. Environmental impact must be evaluated as it pertains to both the environmental and human risk. Examples include chemical hazards, radiation, biological hazards, toxicology and risk analysis studies. Learning about conservation and protection of the environment also requires an understanding of laws and regulations that exist to preserve resources and reduce and/or remediate contamination, but the emphasis should be on the science behind the laws and regulations.  Relating Earth’s resources to a global scale and using technology to collect global resource data for comparative classroom study is recommended. In addition, it is important to connect the industry and the scientific community to the classroom to increase the depth of understanding. Critical thinking and problem-solving skills are important in evaluating resource use, management and conservation. New discoveries and research are important parts of this topic. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Global Environmental Problems and Issues**   * Human population * Potable water quality, use and availability * Climate change * Sustainability * Species depletion and extinction * Air quality * Food production and availability * Deforestation and loss of biodiversity * Waste management (solid and hazardous)   This topic is a culminating section that incorporates the previous topics and applies them to a global or international scale. Case studies, developing and using models, collecting and analyzing water and/or air quality data, conducting or researching population studies and methods of connecting to the real world must be emphasized for this topic. Technology can be used for comparative studies to share local data internationally so that specific, quantifiable data can be compared and used in understanding the impact of some of the environmental problems that exist on a global scale. Researching and investigating environmental factors on a global level contributes to the depth of understanding by applying the environmental science concepts to problem solving and design. Examples of global topics that can be explored include building water or air filtration models, investigating climate change data, monitoring endangered or invasive species, and studying the environmental effects of increasing human population. Researching contemporary discoveries, new technology and new discoveries can lead to improvement in environmental management. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **High School**  **Physical Geology** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Course Description:**  Physical geology is a high school level course that satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.  Physical geology incorporates chemistry, physics and environmental science and introduces students to key concepts, principles and theories within geology.  Investigations are used to understand and explain the behavior of nature in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. | | | | | |
| **Minerals**   * Atoms and elements * Chemical bonding (ionic, covalent, metallic) * Crystallinity (crystal structure) * Criteria of a mineral (crystalline solid, occurs in nature, inorganic, defined chemical composition) * Properties of minerals (hardness, luster, cleavage, streak, crystal shape. fluorescence, flammability, density/specific gravity, malleability)   This unit builds upon the middle school Earth and Space Science strand (beginning in grade 6), where common minerals are tested, minerals are defined and minerals are classified. In addition, the chemistry sections of the physical science syllabus support both mineral properties and crystalline structures (chemical compositions and bonding).  The emphasis at the high school level is to relate the chemical and physical components of minerals to the properties of the minerals. This requires extensive mineral testing, investigations, experimentation, observation, use of technology and models/modeling. The focus must be learning the ways to research, test and evaluate minerals, not in memorization of mineral names or types.  Properties such as cleavage and hardness must be connected to the chemical structure and bonding of the mineral. In addition, the environment in which minerals form should be part of the classification of the mineral, using mineral data to help interpret the environmental conditions that existed during the formation of the mineral. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Igneous**, **Metamorphic and Sedimentary Rocks**  ***Igneous***   * Mafic and felsic rocks and minerals * Intrusive (igneous structures: dikes, sills, batholiths, pegmatites) * Earth’s interior (inner core, outer core, lower mantle, upper mantle, Mohorovicic discontinuity, crust) * Magnetic reversals and Earth’s magnetic field * Thermal energy within the Earth Extrusive (volcanic activity, volcanoes: cinder cones, composite, shield) * Bowen’s Reaction Series (continuous and discontinuous branches)   ***Metamorphic***   * Pressure, stress, temperature and compressional forces * Foliated (regional), non-foliated (contact) * Parent rock and degrees of metamorphism * Metamorphic zones (where metamorphic rocks are found)   ***Sedimentary***   * The ocean * Tides (daily, neap and spring) * Currents (deep and shallow, rip and longshore) * Thermal energy and water density * Waves * Ocean features (ridges, trenches, island systems, abyssal zone, shelves, slopes, reefs, island arcs) * Passive and active continental margins * Division of sedimentary rocks and minerals (chemical, clastic/physical, organic) * Depositional environments * Streams (channels, streambeds, floodplains, cross-bedding, alluvial fans, deltas) * Transgressing and regressing sea levels   This unit builds upon the middle school Earth and Space Science strand (beginning in grade 6). Sedimentary, igneous and metamorphic rocks are introduced, rocks and minerals are tested and classified, plate tectonics, seismic waves and the structure of Earth are studied, and the geologic record is found (including the evidence of climatic variances through Earth’s history). In the middle school Life Science strand, fossils and depositional environments are included as they relate to the documented history of life in the geologic record. In the physical science syllabus, support for waves, thermal energy, currents, pressure and gravity are presented.  At the high school level, geologic, topographic, seismic and aerial maps must be used to locate and recognize igneous, metamorphic and sedimentary structures and features. Technological advances permit the investigation of intrusive structures and the interior of Earth. Connections between the minerals present within each type of rock and the environment formed are important. The processes and environmental conditions that lead to fossil fuel formation (**Note:** this links to the energy resources section below) must include the fossil fuels found in Ohio, nationally and globally.  Bowen’s Reaction Series must be used to develop an understanding of the relationship of cooling temperature, formation of specific igneous minerals and the resulting igneous environment. The focus is on knowing how to use Bowen’s Reaction Series, not to memorize it. Virtual demonstrations and simulations of cooling magma and crystallization of the igneous minerals found on the series can be helpful in conceptualizing the chart.  The magnetic properties of Earth must be examined through the study of real data and evidence. The relationship of polar changes, magnetic stripping, grid north, true north and the north pole must be included in the study of Earth’s magnetic properties.  While the ocean is included within the sedimentary topic, it can be incorporated into other topics. Features found in the ocean must include all types of environments (igneous, metamorphic or sedimentary). Using models (3-D or virtual) with real-time data to simulate waves, tides, currents, feature formation and changing sea levels to explore and investigate the ocean fully is recommended. Interpreting sections of the geologic record to determine sea level changes and depositional environments, including relative age, is also recommended.  Technological advances must be used to illustrate the physical features of the Earth, including the ocean floor. Interpreting geologic history using maps of local cross-sections of bedrock can be related to the geologic history of Ohio, the United States and the Earth. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Earth’s History**  The geologic rock record   * Relative and absolute age * Principles to determine relative age   + Original horizontality   + Superposition   + Cross-cutting relationships * Absolute age * Radiometric dating (isotopes, radioactive decay) * Correct uses of radiometric dating * Combining relative and absolute age data * The geologic time scale * Comprehending geologic time * Climate changes evident through the rock record * Fossil record   This unit builds upon the middle school Earth and Space Science strand (beginning in grade 6), sedimentary, igneous and metamorphic rocks are introduced, rocks and minerals are tested and classified, plate tectonics, seismic waves and the structure of Earth are studied, and the geologic record is found (including uniformitarianism, superposition, cross-cutting relationships and the evidence of climatic variances through Earth’s history). In the middle school Life Science strand, fossils and depositional environments are included as they relate to the documented history of life in the geologic record. In the physical science syllabus, support for radiometric dating, seismic waves, thermal energy, pressure and gravity are presented.  At the high school level, the long-term history of Earth and the analysis of the evidence from the geologic record (including fossil evidence) must be investigated. Using actual sections of the geologic record to interpret, compare and analyze can demonstrate the changes that have occurred in Ohio, in North America and globally.  The emphasis for this unit is to explore the geologic record and the immensity of the geologic record. The analysis of data and evidence found in the variety of dating techniques (both absolute and relative), the complexity of the fossil record, and the impact that improving technology has had on the interpretation and continued updating of what is known about the history of Earth must be investigated. Geologic principles are essential in developing this level of knowledge. These principles must be tested and experienced through modeling, virtually, field studies, research and in-depth investigation. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Plate Tectonics**  • Internal Earth   * Seismic waves   S and P waves  Velocities, reflection, refraction of waves   * Structure of Earth (**Note:** specific layers were part of grade 8)   Asthenosphere  Lithosphere  Mohorovicic boundary (Moho)  Composition of each of the layers of Earth  Gravity, magnetism and isostasy  Thermal energy (geothermal gradient and heat flow)  • Historical review (**Note:** this would include a review of continental drift and sea-floor spreading found in grade 8)   * Paleomagnetism and magnetic anomalies * Paleoclimatology   • Plate motion (**Note:** introduced in grade 8)   * Causes and evidence of plate motion * Measuring plate motion * Characteristics of oceanic and continental plates * Relationship of plate movement and geologic events and features * Mantle plumes   This unit builds upon the middle school Earth and Space Science strand (beginning in grade 6). Sedimentary, igneous and metamorphic rocks are introduced, rocks and minerals are tested and classified, plate tectonics (including the history and evidence for plate tectonics), seismic waves and the interior structure of Earth and the geologic record are found. In the middle school Life Science strand, fossils and depositional environments are included. In the physical science syllabus, support for density, convection, conductivity, motion, kinetic energy, radiometric dating, seismic waves, thermal energy, pressure and gravity are presented.  At the high school level, Earth’s interior and plate tectonics must be investigated at greater depth using models, simulations, actual seismic data, real-time data, satellite data and remote sensing. Relationships between energy, tectonic activity levels and earthquake or volcano predictions, and calculations to obtain the magnitude, focus and epicenter of an earthquake must be included. Evidence and data analysis is the key in understanding this part of the Earth system. For example, GIS/GPS and/or satellite data provide data and evidence for moving plates and changing landscapes (due to tectonic activity).  The causes for plate motion, the evidence of moving plates and the results of plate tectonics must be related to Earth’s past, present and future. The use of evidence to support conclusions and predictions pertaining to plate motion is an important part of this unit. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Earth’s Resources**  • Energy resources   * Renewable and nonrenewable energy sources and efficiency * Alternate energy sources and efficiency * Resource availability * Mining and resource extraction   • Air   * Primary and secondary contaminants * Greenhouse gases   • Water   * Potable water and water quality * Hypoxia, eutrophication   • Soil and sediment   * Desertification * Mass wasting and erosion * Sediment contamination   This unit builds on the Earth and Space Science content from elementary school, when renewable/nonrenewable energy, soils, the atmosphere and water are introduced, to grades 6-8 when Earth’ spheres, Earth’s resources and energy resources are found, and then to biology and physical science (in particular water, air, chemistry and energy topics) syllabi at the high school level.  At the high school science level, renewable and nonrenewable energy resources topics investigate the effectiveness and efficiency for differing types of energy resources at a local, state, national and global level. Feasibility, availability and environmental cost are included in the extraction, storage, use and disposal of both abiotic and biotic resources. Modeling (3-D or virtual), simulations and real-world data must be used to investigate energy resources and exploration. The emphasis must be on current, actual data, contemporary science and technological advances in the field of energy resources.  Relating Earth’s resources (energy, air, water, soil) to a global scale and using technology to collect global resource data for comparative classroom study is recommended. In addition, it is important to connect industry and the scientific community to the classroom to increase the depth of understanding. Critical thinking and problem-solving skills are important in evaluating resource use and conservation.  Smaller scale investigations, such as a field study to monitor stream quality, construction mud issues, stormwater management, nonpoint source-contamination problems (e.g., road-salt runoff, agricultural runoff, parking lot runoff) or thermal water contamination can be useful in developing a deeper understanding of Earth’s resources.  Earth Systems must be used to illustrate the interconnectedness of each of Earth’s spheres (the hydrosphere, lithosphere, atmosphere and biosphere) and the relationship between each type of Earth’s resources. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Glacial Geology**  • Glaciers and glaciation   * Evidence of past glaciers (including features formed through erosion or deposition) * Glacial deposition and erosion (including features formed through erosion or deposition) * Data from ice cores   Historical changes (glacial ages, amounts, locations, particulate matter, correlation to fossil evidence)  Evidence of climate changes throughout Earth’s history   * Glacial distribution and causes of glaciation * Types of glaciers – continental (ice sheets, ice caps), alpine/valley (piedmont, valley, cirque, ice caps) * Glacial structure, formation and movement   This unit builds upon the fourth-grade introduction of Earth’s surface (landforms and features, including glacial geology) and the middle school Earth and Space Science strand, with sedimentary, igneous and metamorphic rocks, sediment and soils, the geologic record and Earth’s history, the cryosphere and the relationship of the analysis of ice cores in understanding changes in climate over thousands of years. Fossils and fossil evidence within the geologic record is found in the Life Science strand, building from second grade through high school biology.  Tracing and tracking glacial history and present-day data for Ohio, the United States and globally is an emphasis for this unit. Scientific data found in the analysis of the geologic record, ice cores and surficial geology should be used to provide the evidence for changes that have occurred over the history of Earth and are observable in the present day. New discoveries, mapping projects, research, contemporary science and technological advances must be included in the study of glacial geology.  Modeling and simulations (3-D or virtual) can be used to illustrate glacial movement and the resulting features. The focus should be on the geologic processes and the criteria for movement, not on memorizing the names of types of glaciers.  Field investigations to map and document evidence of glaciers in the local area (if applicable) or virtual investigations can help demonstrate the resulting glacial features and the impact that ice has had on the surface of Earth throughout history. Real-time data (using remote sensing, satellite, GPS/GIS, aerial photographs/maps) can help support this topic. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |

| **High School**  **Physics** | **Content\* reflected in this standard addressed in the curriculum. Cite evidence.** | **Classify alignment** | **Content\* that needs to be added to curriculum to achieve alignment** | **Degree to which curriculum requires students to achieve cognitive demands\* required by this standard** | **Changes required to guarantee students will achieve the required cognitive demands\*** |
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| **Course Description:**  Physics is a high school level course that satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.  Physics elaborates on the study of the key concepts of motion, forces and energy as they relate to increasingly complex systems and applications that will provide a foundation for further study in science and scientific literacy.  Students engage in investigations to understand and explain motion, forces and energy in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. | | | | | |
| **Motion**   * Graph interpretations * Position vs. time * Velocity vs. time * Acceleration vs. time   In physical science, the concepts of position, displacement, velocity and acceleration were introduced, and straight-line motion involving either uniform velocity or uniform acceleration was investigated and represented in position vs. time graphs, velocity vs. time graphs, motion diagrams and data tables.  In this course, acceleration vs. time graphs are introduced, and more complex graphs are considered that have both positive and negative displacement values and involve motion that occurs in stages (e.g., an object accelerates then moves with constant velocity). Symbols representing acceleration are added to motion diagrams and mathematical analysis of motion becomes increasingly more complex. Motion must be explored through investigation and experimentation. Motion detectors and computer graphing applications can be used to collect and organize data. Computer simulations and video analysis can be used to analyze motion with greater precision.  ***Motion/Graph Interpretations***  Instantaneous velocity for an accelerating object can be determined by calculating the slope of the tangent line for some specific instant on a position vs. time graph. Instantaneous velocity will be the same as average velocity for conditions of constant velocity, but this is rarely the case for accelerating objects. The position vs. time graph for objects increasing in speed will become steeper as they progress and the position vs. time graph for objects decreasing in speed will become less steep.  On a velocity vs. time graph, objects increasing in speed will slope away from the x-axis and objects decreasing in speed will slope toward the x-axis. The slope of a velocity vs. time graph indicates the acceleration, so the graph will be a straight line (not necessarily horizontal) when the acceleration is constant. Acceleration is positive for objects speeding up in a positive direction or objects slowing down in a negative direction. Acceleration is negative for objects slowing down in a positive direction or speeding up in a negative direction. These are not concepts that should be memorized, but can be developed from analyzing the definition of acceleration and the conditions under which acceleration would have these signs. The word “deceleration” should not be used since it provides confusion between slowing down and negative acceleration. The area under the curve for a velocity vs. time graph gives the change in position (displacement) but the absolute position cannot be determined from a velocity vs. time graph.  Objects moving with uniform acceleration will have a horizontal line on an acceleration vs. time graph. This line will be at the x-axis for objects that are either standing still or moving with constant velocity. The area under the curve of an acceleration vs. time graph gives the change in velocity for the object, but the displacement, position and the absolute velocity cannot be determined from an acceleration vs. time graph. The details about motion graphs should not be taught as rules to memorize, but rather as generalizations that can be developed from interpreting the graphs. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **• Problem solving**   * Using graphs (average velocity, instantaneous velocity, acceleration, displacement, change in velocity) * Uniform acceleration including free fall (initial velocity, final velocity, time, displacement, acceleration, average velocity)   Many problems can be solved from interpreting graphs and charts as detailed in the motion graphs section. In addition, when acceleration is constant, average velocity can be calculated by taking the average of the initial and final instantaneous velocities (𝒗𝒂𝒗𝒈=(𝒗𝒇−𝒗𝒊)/2). This relationship does not hold true when the acceleration changes. The equation can be used in conjunction with other kinematics equations to solve increasingly complex problems, including those involving free fall with negligible air resistance in which objects fall with uniform acceleration. Near the surface of Earth, in the absence of other forces, the acceleration of freely falling objects is 9.81 m/s2. Assessments of motion problems, including projectile motion, will not include problems that require the quadratic equation to solve. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| • **Projectiles**   * Independence of horizontal and vertical motion * Problem-solving involving horizontally launched projectiles   ***Projectile Motion***  When an object has both horizontal and vertical components of motion, as in a projectile, the components act independently of each other. For a projectile in the absence of air resistance, this means that horizontally, the projectile will continue to travel at constant speed just like it would if there were no vertical motion. Likewise, vertically the object will accelerate just as it would without any horizontal motion. Problem solving will be limited to solving for the range, time, initial height, initial velocity or final velocity of horizontally launched projectiles with negligible air resistance. While it is not inappropriate to explore more complex projectile problems, it must not be done at the expense of other parts of the curriculum. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Forces, Momentum and Motion**   * Newton’s laws applied to complex problems * Gravitational force and fields * Elastic forces * Friction forces (static and kinetic) * Air resistance and drag * Forces in two dimensions * Adding vector forces * Motion down inclines * Centripetal forces and circular motion * Momentum, impulse and conservation of momentum   **Forces, momentum and motion**  In earlier grades, Newton’s laws of motion were introduced; gravitational forces and fields were described conceptually; the gravitational force (weight) acting on objects near Earth’s surface was calculated; friction forces and drag were addressed conceptually and quantified from force diagrams; and forces required for circular motion were introduced conceptually. In this course, Newton’s laws of motion are applied to mathematically describe and predict the effects of forces on more complex systems of objects and to analyze objects in free fall that experience significant air resistance.  Gravitational forces are studied as a universal phenomenon and gravitational field strength is quantified. Elastic forces and a more detailed look at friction are included. At the atomic level, “contact” forces are actually due to the forces between the charged particles of the objects that appear to be touching. These electric forces are responsible for friction forces, normal forces and other “contact” forces. Air resistance and drag are explained using the particle nature of matter. Projectile motion is introduced and circular motion is quantified. The vector properties of momentum and impulse are introduced and used to analyze elastic and inelastic collisions between objects. Analysis of experimental data collected in laboratory investigations must be used to study forces and momentum. This can include the use of force probes and computer software to collect and analyze data. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Newton’s laws***  Newton’s laws of motion, especially the third law, can be used to solve complex problems that involve systems of many objects that move together as one (e.g., an Atwood’s machine). The equation **a** = **Fnet**/m that was introduced in physical science can be used to solve more complex problems involving systems of objects and situations involving forces that must themselves be quantified (e.g., gravitational forces, elastic forces, friction forces). |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Gravitational Forces and Fields***  Gravitational interactions are very weak compared to other interactions and are difficult to observe unless one of the objects is extremely massive (e.g., the sun, planets, moons). The force law for gravitational interaction states that the strength of the gravitational force is proportional to the product of the two masses and inversely proportional to the square of the distance between the centers of the masses, ***Fg*** *= (G·m1·m2)/r2)*. The proportionality constant, *G,* is called the universal gravitational constant. Problem solving may involve calculating the net force for an object between two massive objects (e.g., Earth-moon system, planet-sun system) or calculating the position of such an object given the net force.  The strength of an object’s (i.e., the source’s) gravitational field at a certain location, ***g***, is given by the gravitational force per unit of mass experienced by another object placed at that location, ***g*** *=* ***Fg*** */* ***m***. Comparing this equation to Newton’s second law can be used to explain why all objects on Earth’s surface accelerate at the same rate in the absence of air resistance. While the gravitational force from another object can be used to determine the field strength at a particular location, the field of the object is always there, even if the object is not interacting with anything else. The field direction is toward the center of the source. Given the gravitational field strength at a certain location, the gravitational force between the source of that field and any object at that location can be calculated. Greater gravitational field strengths result in larger gravitational forces on masses placed in the field. Gravitational fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Field line diagrams are excluded from this course. Distinctions between gravitational and inertial masses are excluded.  A scale indicates weight by measuring the normal force between the object and the surface supporting it. The reading on the scale accurately measures the weight if the system is not accelerating and the net force is zero. However, if the scale is used in an accelerating system as in an elevator, the reading on the scale does not equal the actual weight. The scale reading can be referred to as the “apparent weight.” This apparent weight in accelerating elevators can be explained and calculated using force diagrams and Newton’s laws. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Elastic Forces***  Elastic materials stretch or compress in proportion to the load they support. The mathematical model for the force that a linearly elastic object exerts on another object is ***Felastic*** *= kΔx,* where *Δx* is the displacement of the object from its relaxed position. The direction of the elastic force is always toward the relaxed position of the elastic object. The constant of proportionality, *k,* is the same for compression and extension and depends on the “stiffness” of the elastic object. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Friction Forces***  The amount of kinetic friction between two objects depends on the electric forces between the atoms of the two surfaces sliding past each other. It also depends upon the magnitude of the normal force that pushes the two surfaces together. This can be represented mathematically as ***Fk*** *= μk****FN,*** where *μk* is the coefficient of kinetic friction that depends upon the materials of which the two surfaces are made.  Sometimes friction forces can prevent objects from sliding past each other, even when an external force is applied parallel to the two surfaces that are in contact. This is called static friction, which is mathematically represented by ***Fs*** *≤ μs****FN****.* The maximum amount of static friction possible depends on the types of materials that make up the two surfaces and the magnitude of the normal force pushing the objects together, ***Fsmax*** *= μs****FN***. As long as the external net force is less than or equal to the maximum force of static friction, the objects will not move relative to one another. In this case, the actual static friction force acting on the object will be equal to the net external force acting on the object, but in the opposite direction. If the external net force exceeds the maximum static friction force for the object, the objects will move relative to each other and the friction between them will no longer be static friction, but will be kinetic friction. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Air Resistance and Drag***  Liquids have more drag than gases like air. When an object pushes on the particles in a fluid, the fluid particles can push back on the object according to Newton’s third law and cause a change in motion of the object. This is how helicopters experience lift and how swimmers propel themselves forward. Forces from fluids will only be quantified using Newton’s second law and force diagrams. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Forces in Two Dimensions**   * Adding vector forces * Motion down inclines * Centripetal forces and circular motion   Net forces will be calculated for force vectors with directions between 0° and 360° or a certain angle from a reference (e.g., 37° above the horizontal). Vector addition can be done with trigonometry or by drawing scaled diagrams. Problems can be solved for objects sliding down inclines. The net force, final velocity, time, displacement and acceleration can be calculated. Inclines will either be frictionless or the force of friction will already be quantified. Calculations of friction forces down inclines from the coefficient of friction and the normal force will not be addressed in this course.  An object moves at constant speed in a circular path when there is a constant net force that is always directed at right angles to the direction in motion toward the center of the circle. In this case, the net force causes an acceleration that shows up as a change in direction. If the force is removed, the object will continue in a straight-line path. The nearly circular orbits of planets and satellites result from the force of gravity. Centripetal acceleration is directed toward the center of the circle and can be calculated by the equation *ac = v2/r*, where *v* is the speed of the object and *r* is the radius of the circle. This expression for acceleration can be substituted into Newton’s second law to calculate the centripetal force. Since the centripetal force is a net force, it can be equated to friction (unbanked curves), gravity, elastic force, etc., to perform more complex calculations. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Momentum, Impulse and Conservation of Momentum***  Momentum, ***p***, is a vector quantity that is directly proportional to the mass, *m,* and the velocity, ***v****,* of the object. Momentum is in the same direction the object is moving and can be mathematically represented by the equation ***p*** *= m****v***. The conservation of linear momentum states that the total (net) momentum before an interaction in a closed system is equal to the total momentum after the interaction. In a closed system, linear momentum is always conserved for elastic, inelastic and totally inelastic collisions. While total energy is conserved for any collision, in an elastic collision, the kinetic energy also is conserved. Given the initial motions of two objects, qualitative predictions about the change in motion of the objects due to a collision can be made. Problems can be solved for the initial or final velocities of objects involved in inelastic and totally inelastic collisions. For assessment purposes, momentum may be dealt with in two dimensions conceptually, but calculations will only be done in one dimension. Coefficients of restitution are beyond the scope of this course.  Impulse, *Δ****p***, is the total momentum transfer into or out of a system. Any momentum transfer is the result of interactions with objects outside the system and is directly proportional to both the average net external force acting on the system, ***Favg,*** and the time interval of the interaction, *Δt*. It can mathematically be represented by *Δ****p*** *=* ***pf*** *–* ***pi*** *=* ***Favg*** *Δt*. This equation can be used to justify why momentum changes due to the external force of friction can be ignored when the time of interaction is extremely short. Average force, initial or final velocity, mass or time interval can be calculated in multi-step word problems. For objects that experience a given impulse (e.g., a truck coming to a stop), a variety of force/time combinations are possible. The time could be small, which would require a large force (e.g., the truck crashing into a brick wall to a sudden stop). Conversely, the time could be extended which would result in a much smaller force (e.g., the truck applying the breaks for a long period of time). |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Energy**   * Gravitational potential energy * Energy in springs * Nuclear energy * Work and power * Conservation of energy   **Energy**  In physical science, the role of strong nuclear forces in radioactive decay, half-lives, fission and fusion, and mathematical problem-solving involving kinetic energy, gravitational potential energy, energy conservation and work (when the force and displacement were in the same direction) were introduced. In this course, the concept of gravitational potential energy is understood from the perspective of a field, elastic potential energy is introduced and quantified, nuclear processes are explored further, the concept of mass-energy equivalence is introduced, the concept of work is expanded, power is introduced, and the principle of conservation of energy is applied to increasingly complex situations. Energy must be explored by analyzing data gathered in scientific investigations. Computers and probes can be used to collect and analyze data. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Gravitational Potential Energy***  When two attracting masses interact, the kinetic energies of both objects change but neither is acting as the energy source or the receiver. Instead, the energy is transferred into or out of the gravitational field around the system as gravitational potential energy. A single mass does not have gravitational potential energy. Only the system of attracting masses can have gravitational potential energy. When two masses are moved farther apart, energy is transferred into the field as gravitational potential energy. When two masses are moved closer together, gravitational potential energy is transferred out of the field. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Energy in Springs***  The approximation for the change in the potential elastic energy of an elastic object (e.g., a spring) is  *ΔE elastic = ½ k Δx2*where *Δx* is the distance the elastic object is stretched or compressed from its relaxed length. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Nuclear Energy***  Alpha, beta, gamma and positron emission each have different properties and result in different changes to the nucleus. The identity of new elements can be predicted for radioisotopes that undergo alpha or beta decay. During nuclear interactions, the transfer of energy out of a system is directly proportional to the change in mass of the system as expressed by *E = mc2,* which is known as the equation for mass-energy equivalence. A very small loss in mass is accompanied by a release of a large amount of energy. In nuclear processes such as nuclear decay, fission and fusion, the mass of the product is less than the mass of the original nuclei. The missing mass appears as energy. This energy can be calculated for fission and fusion when given the masses of the particle(s) formed and the masses of the particle(s) that interacted to produce them. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Work and Power***  Work can be calculated for situations in which the force and the displacement are at angles to one another using the equation *W =* ***FΔx****(cosθ)* where *W* is the work, ***F*** is the force, ***Δx*** is the displacement, and *θ* is the angle between the force and the displacement. This means when the force and the displacement are at right angles, no work is done and no energy is transferred between the objects. Such is the case for circular motion.  The rate of energy change or transfer is called power (*P*) and can be mathematically represented by *P = ΔE / Δt* or *P = W / Δt*. Power is a scalar property. The unit of power is the watt (W), which is equivalent to one Joule of energy transferred in one second (J/s). |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Conservation of Energy***  The total initial energy of the system and the energy entering the system are equal to the total final energy of the system and the energy leaving the system. Although the various forms of energy appear very different, each can be measured in a way that makes it possible to keep track of how much of one form is converted into another. Situations involving energy transformations can be represented with verbal or written descriptions, energy diagrams and mathematical equations. Translations can be made between these representations.  The conservation of energy principle applies to any defined system and time interval within a situation or event in which there are no nuclear changes that involve mass-energy equivalency. The system and time interval may be defined to focus on one particular aspect of the event. The defined system and time interval may then be changed to obtain information about different aspects of the same event. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Waves**   * Wave properties * Conservation of energy * Reflection * Refraction * Interference * Diffraction   **Waves**  In earlier grades, the electromagnetic spectrum and basic properties (wavelength, frequency, amplitude) and behaviors of waves (absorption, reflection, transmission, refraction, interference, diffraction) were introduced. In this course, conservation of energy is applied to waves, and the measurable properties of waves (wavelength, frequency, amplitude) are used to mathematically describe the behavior of waves (index of refraction, law of reflection, single- and double-slit diffraction). The wavelet model of wave propagation and interactions is not addressed in this course. Waves must be explored experimentally in the laboratory. This may include, but is not limited to, water waves, waves in springs, the interaction of light with mirrors, lenses, barriers with one or two slits, and diffraction gratings. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Wave properties**   * Conservation of energy * Reflection * Refraction * Interference * Diffraction   When a wave reaches a barrier or a new medium, a portion of its energy is reflected at the boundary and a portion of the energy passes into the new medium. Some of the energy that passes to the new medium may be absorbed by the medium and transformed to other forms of energy, usually thermal energy, and some continues as a wave in the new medium. Some of the energy also may be dissipated, no longer part of the wave since it has been transformed into thermal energy or transferred out of the system due to the interaction of the system with surrounding objects. Usually all of these processes occur simultaneously, but the total amount of energy must remain constant.  When waves bounce off barriers (reflection), the angle at which a wave approaches the barrier (angle of incidence) equals the angle at which the wave reflects off the barrier (angle of reflection). When a wave travels from a two-dimensional (e.g., surface water, seismic waves) or three-dimensional (e.g., sound, electromagnetic waves) medium into another medium in which the wave travels at a different speed, both the speed and the wavelength of the transferred wave change. Depending on the angle between the wave and the boundary, the direction of the wave also can change resulting in refraction. The amount of bending of waves around barriers or small openings (diffraction) increases with decreasing wavelength. When the wavelength is smaller than the obstacle or opening, no noticeable diffraction occurs. Standing waves and interference patterns between two sources are included in this topic. As waves pass through a single or double slit, diffraction patterns are created with alternating lines of constructive and destructive interference. The diffraction patterns demonstrate predictable changes as the width of the slit(s), spacing between the slits and/or the wavelength of waves passing through the slits changes. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Light phenomena**   * Ray diagrams (propagation of light) * Law of reflection (equal angles) * Snell’s law * Diffraction patterns * Wave – particle duality of light * Visible spectrum and color   The path of light waves can be represented with ray diagrams to show reflection and refraction through converging lenses, diverging lenses and plane mirrors. Since light is a wave, the law of reflection applies. Snell’s law, *n1sinθ1 = n2sinθ2*, quantifies refraction in which *n* is the index of refraction of the medium and *θ* is the angle the wave enters or leaves the medium, when measured from the normal line. The index of refraction of a material can be calculated by the equation *n = c/v*, where *n* is the index of refraction of a material, *v* is the speed of light through the material, and *c* is the speed of light in a vacuum. Diffraction patterns of light must be addressed, including patterns from diffraction gratings.  There are two models of how radiant energy travels through space at the speed of light. One model is that the radiation travels in discrete packets of energy called photons that are continuously emitted from an object in all directions. The energy of these photons is directly proportional to the frequency of the electromagnetic radiation. This particle-like model is called the photon model of light energy transfer. A second model is that radiant energy travels like a wave that spreads out in all directions from a source. This wave-like model is called the electromagnetic wave model of light energy transfer. Strong scientific evidence supports both the particle-like model and wave-like model. Depending on the problem scientists are trying to solve, either the particle-like model or the wave-like model of radiant energy transfer is used. Students are not required to know the details of the evidence that supports either model at this level.  Humans can only perceive a very narrow portion of the electromagnetic spectrum. Radiant energy from the sun or a light bulb filament is a mixture of all the colors of light (visible light spectrum). The different colors correspond to different radiant energies. When white light hits an object, the pigments in the object reflect one or more colors in all directions and absorb the other colors. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **Electricity and Magnetism**   * Charging objects (friction, contact and induction) * Coulomb’s law * Electric fields and electric potential energy * DC circuits * Ohm’s law * Series circuits * Parallel circuits * Mixed circuits * Applying conservation of charge and energy (junction and loop rules) * Magnetic fields and energy * Electromagnetic interactions   **Electricity and Magnetism**  In earlier grades, the following concepts were addressed: conceptual treatment of electric and magnetic potential energy; the relative number of subatomic particles present in charged and neutral objects; attraction and repulsion between electrical charges and magnetic poles; the concept of fields to conceptually explain forces at a distance; the concepts of current, potential difference (voltage) and resistance to explain circuits conceptually; and connections between electricity and magnetism as observed in electromagnets, motors and generators. In this course, the details of electrical and magnetic forces and energy are further explored and can be used as further examples of energy and forces affecting motion. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Charging Objects (friction, contact and induction)***  For all methods of charging neutral objects, one object/system ends up with a surplus of positive charge and the other object/system ends up with the same amount of surplus of negative charge. This supports the law of conservation of charge that states that charges cannot be created or destroyed. Tracing the movement of electrons for each step in different ways of charging objects (rubbing together two neutral materials to charge by friction; charging by contact and by induction) can explain the differences between them. When an electrical conductor is charged, the charge “spreads out” over the surface. When an electrical insulator is charged, the excess or deficit of electrons on the surface is localized to a small area of the insulator.  There can be electrical interactions between charged and neutral objects. Metal conductors have a lattice of fixed positively charged metal ions surrounded by a “sea” of negatively charged electrons that flow freely within the lattice. If the neutral object is a metal conductor, the free electrons in the metal are attracted toward or repelled away from the charged object. As a result, one side of the conductor has an excess of electrons and the opposite side has an electron deficit. This separation of charges on the neutral conductor can result in a net attractive force between the neutral conductor and the charged object. When a charged object is near a neutral insulator, the electron cloud of each insulator atom shifts position slightly so it is no longer centered on the nucleus. The separation of charge is very small, much less than the diameter of the atom. Still, this small separation of charges for billions of neutral insulator particles can result in a net attractive force between the neutral insulator and the charged object. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Coulomb’s law***  Two charged objects, which are small compared to the distance between them, can be modeled as point charges. The forces between point charges are proportional to the product of the charges and inversely proportional to the square of the distance between the point charges [*Fe = ke q1 q2) / r2*]. Problems may be solved for the electric force, the amount of charge on one of the two objects or the distance between the two objects. Problems also may be solved for three- or four-point charges in a line if the vector sum of the forces is zero. This can be explored experimentally through computer simulations. Electric forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. However, gravitational forces are only attractive and can accumulate in massive objects to produce a large and noticeable effect whereas electric forces are both attractive and repulsive and tend to cancel each other out. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Electric Fields and Electric Potential Energy***  The strength of the electrical field of a charged object at a certain location is given by the electric force per unit charge experienced by another charged object placed at that location, ***E = Fe*** */ q*. This equation can be used to calculate the electric field strength, the electric force or the electric charge. However, the electric field is always there, even if the object is not interacting with anything else. The direction of the electric field at a certain location is parallel to the direction of the electrical force on a positively charged object at that location. The electric field caused by a collection of charges is equal to the vector sum of the electric fields caused by the individual charges (superposition of charge). This topic can be explored experimentally through computer simulations. Greater electric field strengths result in larger electric forces on electrically charged objects placed in the field. Electric fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Electric field diagrams for a dipole, two-point charges (both positive, both negative, one positive and one negative) and parallel capacitor plates are included. Field line diagrams are excluded from this course.  The concept of electric potential energy can be understood from the perspective of an electric field. When two attracting or repelling charges interact, the kinetic energies of both objects change but neither is acting as the energy source or the receiver. Instead, the energy is transferred into or out of the electric field around the system as electric potential energy. A single charge does not have electric potential energy. Only the system of attracting or repelling charges can have electric potential energy. When the distance between the attracting or repelling charges changes, there is a change in the electric potential energy of the system. When two opposite charges are moved farther apart or two like charges are moved close together, energy is transferred into the field as electric potential energy. When two opposite charges are moved closer together or two like charges are moved far apart, electric potential energy is transferred out of the field. When a charge is transferred from one object to another, work is required to separate the positive and negative charges. If there is no change in kinetic energy and no energy is transferred out of the system, the work increases the electric potential energy of the system. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| **DC circuits**   * Ohm’s law * Series circuits * Parallel circuits * Mixed circuits * Applying conservation of charge and energy (junction and loop rules)   Once a circuit is switched on, the current and potential difference are experienced almost instantaneously in all parts of the circuit even though the electrons are only moving at speeds of a few centimeters per hour in a current-carrying wire. It is the electric field that travels instantaneously through all parts of the circuit, moving the electrons that are already present in the wire. Since electrical charge is conserved, in a closed system such as a circuit, the current flowing into a branch point junction must equal the total current flowing out of the junction (junction rule).  Resistance is measured in ohms and has different cumulative effects when added to series and parallel circuits. The potential difference, or voltage (*ΔV*), across an energy source is the potential energy difference (*ΔE*) supplied by the energy source per unit charge (*q*) (*ΔV = ΔE/q*). The electric potential difference across a resistor is the product of the current and the resistance (*ΔV = I R*). In physics, only ohmic resistors will be studied. When potential difference vs. current is plotted for an ohmic resistor, the graph will be a straight line and the value of the slope will be the resistance. Since energy is conserved for any closed loop, the energy put into the system by the battery must equal the energy that is transformed by the resistors (loop rule). For circuits with resistors in series, this means that *ΔVbattery = ΔV1 + ΔV2 + ΔV3 +….* The rate of energy transfer (power) across each resistor is equal to the product of the current through and the voltage drop across each resistor (*P = ΔV I*) and *Pbattery = I ΔV1 + I ΔV2 + I ΔV3 +… = IΔVbattery.* Equations should be understood conceptually and used to calculate the current or potential difference at different locations of a parallel, series or mixed circuit. However, the names of the laws (e.g., Ohm’s law, Kirchoff’s loop law) will not be assessed. Measuring and analyzing current, voltage and resistance in parallel, series and mixed circuits must be provided. This can be done with traditional laboratory equipment and through computer simulations. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Magnetic Fields and Energy***  The direction of the magnetic field at any point in space is the equilibrium direction of the north end of a compass placed at that point. Magnetic fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Field line diagrams are excluded from this course. Calculations for the magnetic field strength are not required at this grade level, but it is important to note that greater magnetic fields result in larger magnetic forces on magnetic objects or moving charges placed in the field. The concept of magnetic potential energy can be understood from the perspective of a magnetic field. When two attracting or repelling magnetic poles interact, the kinetic energies of both objects change but neither is acting as the energy source or the receiver. Instead, the energy is transferred into or out of the magnetic field around the system as magnetic potential energy. A single magnetic pole does not have magnetic potential energy. Only the system of attracting or repelling poles can have magnetic potential energy. When the distance between the attracting or repelling poles changes, there is a change in the magnetic potential energy of the system. When two magnetically attracting objects are moved farther apart or two magnetically repelling objects are moved close together, energy is transferred into the field as magnetic potential energy. When two magnetically attracting objects are moved closer together or two magnetically repelling objects are moved far apart, magnetic potential energy is transferred out of the field. Work is required to separate two magnetically attracting objects. If there is no change in kinetic energy and no energy is transferred out of the system, the work done on the system increases the magnetic potential energy of the system. In this course, the concepts of magnetic fields and magnetic potential energy will not be addressed mathematically. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |
| ***Electromagnetic Interactions***  Magnetic forces are very closely related to electric forces. Even though they appear to be distinct from each other, they are thought of as different aspects of a single electromagnetic force. A flow of charged particles (including an electric current) creates a magnetic field around the moving particles or the current carrying wire. Motion in a nearby magnet is evidence of this field. Electric currents in Earth’s interior give Earth an extensive magnetic field, which is detected from the orientation of compass needles. The motion of electrically charged particles in atoms produces magnetic fields. Usually these magnetic fields in an atom are randomly oriented and therefore cancel each other out. In magnetic materials, the subatomic magnetic fields are aligned, adding to give a macroscopic magnetic field.  A moving charged particle interacts with a magnetic field. The magnetic force that acts on a moving charged particle in a magnetic field is perpendicular to both the magnetic field and to the direction of motion of the charged particle. The magnitude of the magnetic force depends on the speed of the moving particle, the magnitude of the charge of the particle, the strength of the magnetic field, and the angle between the velocity and the magnetic field. There is no magnetic force on a particle moving parallel to the magnetic field. Calculations of the magnetic force acting on moving particles are not required at this grade level. Moving charged particles in magnetic fields typically follow spiral trajectories since the force is perpendicular to the motion.  A changing magnetic field creates an electric field. If a closed conducting path, such as a wire, is in  the vicinity of a changing magnetic field, a current may flow through the wire. A changing magnetic field can be created in a closed loop of wire if the magnet and the wire move relative to one another. This can cause a current to be induced in the wire. The strength of the current depends upon the strength of the magnetic field, the velocity of the relative motion and the number of loops in the wire. Calculations for current induced in a wire or coil of wire is not required at this level. A changing electric field creates a magnetic field and a changing magnetic field creates an electric field. Thus, radiant energy travels in electromagnetic waves produced by changing the motion of charges or by changing magnetic fields. Therefore, electromagnetic radiation is a pattern of changing electric and magnetic fields that travel at the speed of light.  The interplay of electric and magnetic forces is the basis for many modern technologies that convert mechanical energy to electrical energy (generators) or electrical energy to mechanical energy (electric motors), as well as devices that produce or receive electromagnetic waves. Therefore, coils of wire and magnets are found in many electronic devices including speakers, microphones, generators and electric motors. The interactions between electricity and magnetism must be explored in the laboratory setting. Experiments with the inner workings of motors, generators and electromagnets must be conducted. Current technologies using these principles must be explored. |  | **\_\_\_ Full**  **\_\_\_ Partial**  **\_\_\_ No** |  | **\_\_\_ Fully**  **\_\_\_ Partially**  **\_\_\_ Does not** |  |